

Long-Term Gas Supply Disruption

Impacts on New Zealand's Electricity Generation System

A Technical Report
September 2009



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This report has been prepared by the New Zealand Centre for Advanced Engineering.
The Centre gratefully acknowledges the support and sponsorship of Transpower which made this study possible.

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VERSION	DESCRIPTION	AUTHOR	CAENZ APPROVAL	DATE
1.0	Draft	Name: John Duncan	Name: Scott Caldwell	28/8/09
2.0	Review & Modification	Name: John Duncan	Name: George Hooper	4/9/09
3.0	Issued for Use	Name: John Duncan	Name: George Hooper	16/9/09

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1. Introduction

Natural gas presently provides nearly one quarter of New Zealand's primary energy and, since the production started at the Maui gas field over twenty years ago, the quantity of gas used in electricity generation has more than doubled, with about one quarter of electricity demand now generated from natural gas. Gas has proven to be a competitive and versatile thermal fuel in the industrial, commercial and residential markets and is a necessary and reliable complement to renewable resources in electricity generation. Underpinning the attractiveness of gas is efficient and cost-effective combustion and generation technology and a highly reliable system of supply.

Gas is supplied from the production and processing facilities in Taranaki to the principal gas-fired power stations through a high-pressure transmission system. Whilst this system has operated to a high level of reliability since the 1970's, it does not have built into its design¹ the reliability criteria, such as N-1, applied in electricity transmission networks whereby the loss of a linkage within the system will not cause a failure elsewhere. The reliability of the gas transmission system can be ascribed to its engineering and operational competence rather than the availability of back-up supplies through the design of the network layout.

The few failures in gas supplies which have occurred have generally been of short duration and caused by damage to the transmission pipelines, such as washout by flooding or impact by digging machinery operating adjacent to the buried pipeline. Unlike the electricity transmission network, there is some storage capacity within the gas system as the gas is transmitted at high pressure (up to 86 bar) and consumers can be supplied for some time as the gas decompresses in the pipeline downstream of the damage. During the washout of the Hawkes Bay pipeline in 2004, there was sufficient compressed gas, or linepack, in the pipeline to supply the residential gas market for the week the pipeline was out of operation. However, larger industrial consumers could not receive gas during this period.

Government and the gas industry is aware of this potential vulnerability to gas supplies and, through the Gas Industry Company, is replacing existing industry arrangements for dealing with critical contingencies with regulations under the Gas Act. The resulting Gas Governance (Critical Contingency Management) Regulations 2008 include, *inter alia*, the appointment of a critical contingency operator, the preparation of critical contingency management plans, and curtailment arrangements to reduce gas supply to consumers. They are intended to permit the more efficient management of situations when gas supply is affected by short-term production outage or physical problems with the transmission system which the market proves unable to manage although they do not specify a maximum period for which the contingency arrangements will be applied.

One of CAENZ's principal areas of activity is developing a more thorough understanding of the resilience of New Zealand infrastructure to natural hazards and the inter-dependencies between any vulnerabilities and the wider economy. The natural gas supply system is a significant part of this infrastructure and little publicized work has been undertaken to investigate the impact of

¹ Except at major compressor stations and pressure reduction stations

sustained failures within the supply system on gas availability and the consequent impact on gas consumers, in particular the electricity generators which have a wider impact on electricity consumers.

This lack of investigation is due in part to the high level of reliability of gas supplies. Whilst gas supplies may be crucial to many commercial and industrial consumers, relatively few have back-up measures in place to replace gas if it were not available. In some cases this is because the consumers' operations require the particular properties of natural gas but in most cases it is due to the costs of making provision for back-up fuels which is deemed unnecessary given the high reliability of natural gas supply. However, this is not to say that situations cannot occur which result in a sustained shortfall of gas supplies. It is the intention of this investigation to provide a better understanding of the impact of breakdowns in the gas supply system on the availability of gas to consumers and the consequent impact on their operations.

Specific attention is given to the impact of gas availability on electricity generation and the interplay between gas and electricity demand when gas is in short supply.

2. Approach

This study is a high level analysis of the impact on the New Zealand gas and electricity sectors of failures in natural gas supplies. The failures investigated are sufficiently extended to have an impact on the operation of gas consumers and to be beyond the intended scope of the gas contingency regulations. When carrying out the analysis, a number of key topics were addressed:

- Determination of changes to gas intakes and offtakes from the gas transmission system resulting from failures in the gas supply system and the identification of critical points within the system where failure will have major impacts on gas supplies.
- Changes in energy consumption resulting from gas shortages, in particular actions taken by electricity generators and others to reduce energy consumption or switch fuels. In the industrial and commercial sectors major gas users were canvassed and consumer responses during actual gas failures reviewed. The response of the electricity generators to constraints in gas availability is modeled to determine changes in output from gas-fired plants and changes to the mix of generation types.
- The allocation of gas supplies when production does not meet demand.
- Identification of secondary effects arising from gas shortages, such as constraints on the supply of alternative fuels.
- Identification of measures which can reduce the impact of gas shortages.

A series of scenarios has been developed to assess the impact of a gas shortfall on gas and electricity markets. As the New Zealand gas transportation system is made up of two distinct transmission systems with a number of inter-connections and gas intake points, it is not sufficient to uniformly reduce the amount of gas to all consumers in all locations as the supply and transportation system will respond to rectify supply constraints as best it can. The scenarios have been set under the following assumptions:

- The scenarios are based on credible events so that the location of the event and their impact on gas supply can be predicted with some authenticity. This permits a realistic assessment of the response of the supply system and subsequent allocation of gas to the various market sectors.
- No probabilities have been assigned to the events occurring. The New Zealand natural gas supply system operates to a high level of reliability and some of the events used in the analysis have not occurred during the history of the industry. Some are based on natural events, e.g. volcanic action and washouts, which occur at extremely infrequent periods but could have a major impact on gas supply.
- The reassignment of gas flows in each scenario is based on a simple static model using fixed gas supply and demand assumptions. In practice, gas supply and demand fluctuate significantly and transient models are used to analyse and manage the transmission systems.
- No account has been made of gas contracts or price in allocating gas available to consumers. This allocation has been made simply on gas availability and the curtailment bands in the contingency regulations.

- The impact of gas shortages on the generation of electricity is assessed using a dispatch model of the New Zealand electricity system with power system data obtained from the Electricity Commission's 2008 Statement of Opportunities and other public information.
- Gas sector data is obtained from MED publications, gas transmission companies' information disclosure documents and discussions with industry participants.

Five scenarios are considered in this analysis and are discussed in Sections 7 to 11 of the report:

- Section 7: Major Disaster in Taranaki Area through volcanic activity at Mt Taranaki
- Section 8: Limited Gas Supply North of Taranaki resulting from fire at the Mokau compressor station
- Section 9: Limited Gas Supply North of Rotowaro due to fire at the Rotowaro compressor station
- Section 10: Disruption to MDL Pipeline Operation by landslip damage
- Section 11: Disruption to Maui Gas Supplies due to fire at the Oaonui Production Station

3. Gas Supply and Consumption

Natural gas is supplied throughout the North Island by high-pressure transmission pipeline to a wide variety of consumers. The larger gas users, such as the gas-fired power stations, petrochemical plants and major industrial sites, are supplied directly from the transmission system whilst the large number of smaller consumers are supplied through local low pressure gas distribution networks.

Usage	PJ Gas	Comments
Electricity Generation	75	Huntly steam and gas turbines, Otahuhu, TCC
Co-Generation	18	Southdown and five smaller sites
Petrochemicals	24	Methanol and ammonia urea production
Industrial	35	Over 1,300 consumers
Commercial	5	Over 7,600 consumers
Residential	6	Over 230,000 consumers
Total Gas Consumption	162	

Table 1: Natural gas consumption for 2007²

Note: Methanol production has increased subsequently, with re-commissioning of the Motonui facility (single stream). Production dependent on gas availability and world markets.

All natural gas used in New Zealand is produced in Taranaki. The industry has been dominated by the large offshore Maui gas field since it came on-stream in the early 1980's but which is now in decline and is no longer the largest producer of gas. Pohokura, which commenced production in 2006, is now the largest producer and will be complemented offshore by Kupe which is presently being developed. Onshore, Kapuni, the original gas field, continues to produce at a consistent rate and has potential for redevelopment to maintain its rate of production for some years. A number of small onshore fields provide the remainder of gas produced as shown in Table2.

When investigating the impact of a gas shortage on consumption, and particularly the response of the electricity generators, it is most informative to consider the peak rates of production and consumption rather than annual totals. Peak rates are best sourced from the annual transmission pipeline capacity disclosure information published by Maui Development Ltd and Vector Gas Ltd, the owners of the two gas transmission pipeline systems. These documents not only provide quantities of peak weekly intakes and offtakes but also the location of these

² From New Zealand Energy Data File, MED, June 2008

flows on the pipeline system, which identifies the principal consumers of gas. Figure 1 summarises the peak gas intakes and offtakes during 2008

Field	Location	PJ Gas	Comments
Maui	Offshore	52	Maximum production 175 PJ in 1992 and 1999
Kapuni	Onshore	21	Commenced 1969
Pohokura	Offshore	70	Commenced 2006
Kupe	Offshore		Under development, will produce 20 PJ pa
Smaller Fields	Onshore	23	
Total Gas Production		165	

Table 2: Natural gas production for 2007³

3.1 Transmission Pipeline Systems

There are two pipeline transmission systems in New Zealand. The Maui Development Ltd (MDL) pipeline runs from the Oaonui production station in southwest Taranaki, where Maui gas is processed, to Rotowaro near Huntly. It was constructed specifically to supply gas to the major gas projects built in conjunction with the Maui field, including the Huntly power station, and has a capacity of 330 TJ/day. The other system is owned by Vector and supplies gas to the regional gas markets, including some major consumers such as the Taranaki combined cycle power plant (TCC) in Taranaki and CHH in the Bay of Plenty. Generally it is designed to carry smaller quantities of gas than the MDL system and significantly only has a capacity of 33 TJ/day in the pipeline connecting Taranaki to the Waikato.

The MDL pipeline runs from Oaonui to Rotowaro and is shown in the Figure 1 as a blue line:

- Intake points to the MDL pipeline are at Oaonui, where Maui gas is received, and a number of points at Tikorangi, north of New Plymouth, where gas is received from Pohokura and the smaller onshore Taranaki fields.
- Principal offtake points are the New Plymouth and Huntly power stations, the Methanex plants at Waitara and at the interconnections to the Vector pipeline system at Frankley Road (New Plymouth), Pokuru (Te Awamutu) and Rotowaro. Frankley Road can also act as an intake point when gas is run from the Vector system to the MDL pipeline.
- The longest section, from Frankley Road to Rotowaro, has a diameter of 750 mm and a maximum capacity of 330 TJ/day.

³ From New Zealand Energy Data File, MED, June 2008

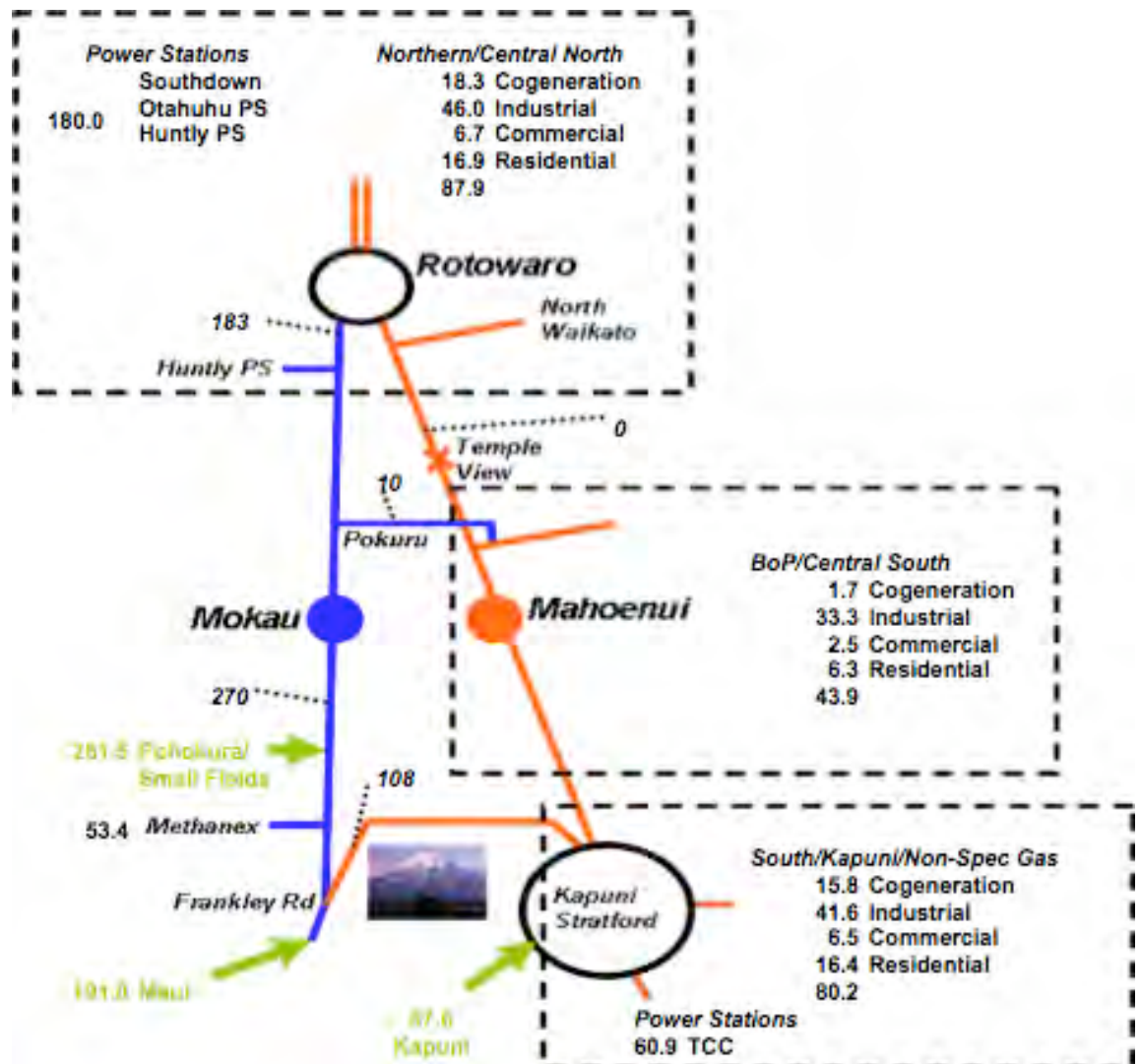


Figure 1: Maximum weekly gas production and consumption for 2008 (TJ/day)

Note: As derived in the study.

The Vector system, shown in orange, consists of several key sections:

- Frankley Road interconnection point with MDL to the Kapuni Gas Treatment Plant. The major offtake point on this line is the TCC power station, with a local lateral from Kapuni to the Ballance ammonia-urea plant. In the future it will include the offtake for the 200 MW Stratford open cycle power station and the intake point from the Kupe gas field will be in the Kapuni area. It consists of 500 mm pipeline and, given the relatively short length of this pipeline section, should not present a constraint to the gas flow rates considered in this analysis.
- The South system, supplying all gas consumers south of the Kapuni gas treatment plant, including Wellington and the Hawkes Bay.
- The Central (South) system running northwards from the Kapuni gas treatment plant to Temple View (Hamilton), via the Pokuru offtake point near Te Awamutu. The Pokuru to

Temple View section is generally closed off, but can be opened to supply gas from Kapuni into the Vector system north of Hamilton. This part of the system comprises 200 mm pipeline, providing a maximum northward capacity from Kapuni of 33 TJ/day, about 10% of the parallel MDL pipeline.

- The Bay of Plenty system runs eastward from Pokuru and supplies the Kinleith, Kawerau, Taupo, Tauranga and Gisborne areas. It receives gas at Pokuru from both the Vector South (Central) system and the MDL pipeline.
- The Central (North) system runs southward from Rotowaro to Temple View supplying Te Rapa and Hamilton and eastwards to Morrinsville, Waitoa and Cambridge.⁴
- The North system, extending from Rotowaro to north of Whangarei, supplies Auckland and major users such as the Otahuhu and Southdown power stations, NZ Steel at Glenbrook and the Marsden Point oil refinery. The proposed Rodney combined cycle power station, situated north of Auckland, will also be supplied from this part of the Vector system. To supply the full demand of the Rodney power station, the Rotowaro compressor station and pipelines from Rotowaro through Auckland will need to be upgraded. Gas is supplied into the North system at Rotowaro from the MDL pipeline and could also be supplied from the Vector Central (South) system if the valve at Temple View is opened.

The Vector and MDL disclosure documents do not include all intake and offtake points in the New Zealand gas transmission system:

- Gas intake from the Kapuni field has been taken from annual MED production data.
- The Whareroa dairy factory in Hawera and the Ballance ammonia urea plant take non-specification gas from the Kapuni gas treatment plant. Use of this gas at Whareroa is estimated on the size of the co-generation plant.

Each of the Vector pipeline systems supplies a variety of industrial, commercial and residential gas consumers. The large majority of consumers is supplied via lower pressure gas distribution networks but some of the larger industrial gas users, such as the power stations, refinery, steel mill, pulp and paper mills and dairy factories, are supplied directly from the transmission system.

3.2 Gas Consumers

Using the pipeline companies' disclosure documents, offtakes have been aggregated into the principal consumer categories for each of the major sections of the transmission network: the MDL pipeline and the Vector system north of Rotowaro, south of Temple View and south of New Plymouth. The major power stations, including Southdown, are listed separately as the impact of gas shortages will fall primarily on these plants.

The aggregated consumption data shown in Figure 1 is based on the weekly maxima for the individual offtake points rather than the maximum offtake for the whole system. As the maximum weeks for all offtake points do not coincide (some in the winter, others in

⁴ Vector's Central South pipeline has insufficient capacity to supply the Central North demand. By isolating at Temple View, the Central North load is supplied through the Rotowaro compressor station.

spring/summer where the dairy industry dominates), the gas inputs and outputs in Figure 1 do not match up. Also, the maximum daily rates when annualized will exceed the actual annual gas throughput because of this same seasonality of demand. Other simplifying assumptions have been made in Figure 1:

- Offtakes for most of the larger gas users can be specifically identified and categorized. These include the power stations and major industrial plants such as paper mills, dairy factories and the Glenbrook steel mill.
- Consumption of gas at co-generation plants (excluding Southdown) has been based on the size of the generating plant to distinguish it from gas used for thermal load.
- The residual gas offtake after power stations and large industrial users has been disaggregated as 44% light industrial, 16% commercial and 40% residential for each section of the Vector transmission network⁵.

In reality, gas consumption and load on the gas transmission systems varies considerably between seasons and between years, as illustrated in Figure 2. However, the snapshot of consumption provided by the disclosure information illustrates the key conclusions arising from this scenario analysis. Capturing the variations in consumption would require considerably more analysis time than allowed in this project.

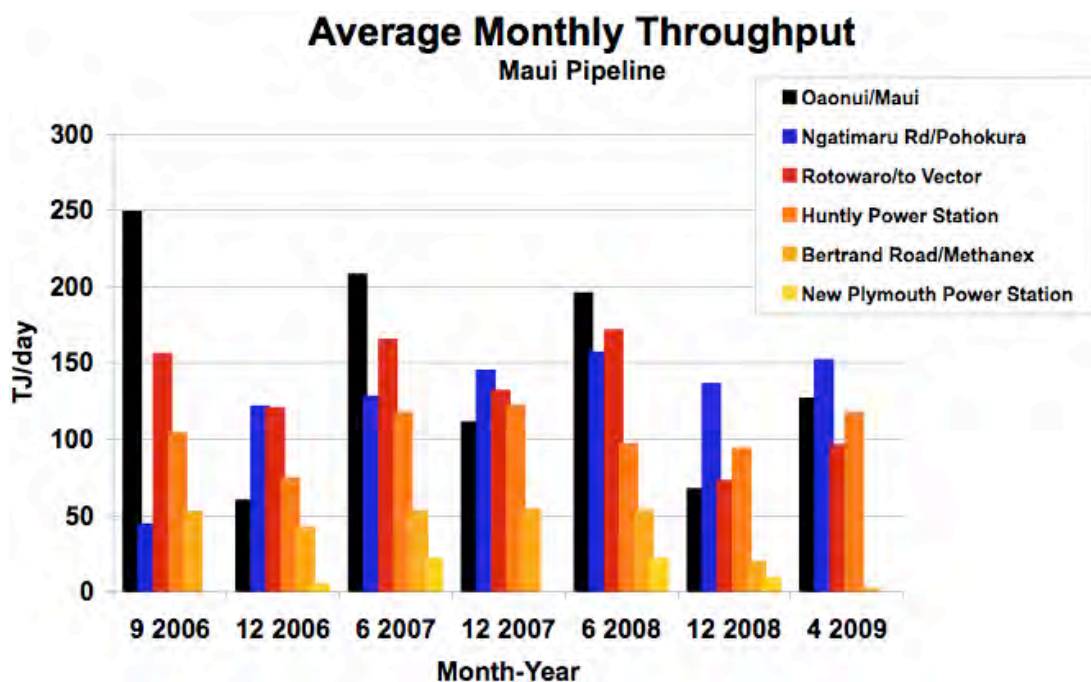


Figure 2: Average monthly throughput of Maui pipeline

Source: Maui Pipeline Open Access Transmission Information System (OATIS)

⁵New Zealand Energy Data File, MED, June 2008. The proportions for maximum offtake have been derived from annual consumption data by doubling the residential gas consumption which is highly biased towards the winter months (4:1 winter: summer consumption).

4 Base Case

A base case with full gas availability is required as a benchmark against which to assess the impact of gas shortages. This should reflect anticipated changes to existing gas supply and consumption expected in the next few years and which need to be accounted for in the gas scenarios to be analysed. The primary assumptions used in the base case include:

- Industrial, commercial and residential maximum gas consumption will be the same as those in the 2008 gas transmission disclosure data.
- The New Plymouth power station will be permanently retired.
- The Huntly 1,000 MW steam turbine plant will burn only coal. Gas at the Huntly site will be used in the e3p CCGT plant and the smaller open cycle unit.
- A 200 MW open cycle gas turbine power station will be constructed near Stratford (Stratford OCGT, SOCGT) and connected to the Vector Frankly Road-Kapuni pipeline.
- Gas consumption at the power stations is based on their technical performance rather than the offtakes in the gas disclosure data. This performance is summarized in Section 6⁶.
- Maximum available gas production is largely reflected in the gas disclosure data. This is discussed in Section 4.1.
- The Kupe gas field will be brought on-stream, capable of supplying 70 TJ/day into the Kapuni area.
- Gas available for electricity generation is assumed to be the difference between the maximum deliverability from the gas fields less the maximum consumption of the industrial, commercial and residential gas users. This provides a rather conservative estimate of gas availability, as the latter users' maxima will not always coincide.

Figure 3 summarises the base case in which maximum production is balanced with consumption. The combined gas quantity shown for the five power stations is the maximum gas available to them and is in excess of their combined maximum gas requirement.

4.1 Gas Field Deliverability

The surpluses and constraints on gas supply to power stations under the various scenarios, except constraints due to pipeline capacity limitations, will depend on the maximum deliverability of gas from the various fields. Gas deliverability typically plateaus over the life of the field and then declines, particularly as depletion is approached, but can be sustained or expanded by extending field life through advanced production techniques, the subsequent addition of reserves or by the expansion of gas production and processing capacities.

⁶ The Rodney combined cycle gas turbine power station is not included in the analysis. If constructed, it will be connected to Vector's Northern pipeline north of Auckland

With potential for increased maximum deliverability in some fields and reductions in others, the 2008 maximum offtake data in the MDL and Vector pipeline disclosure documents provide a realistic indication of gas availability, particularly given the ongoing efforts of the production companies to improve productivity in existing fields.

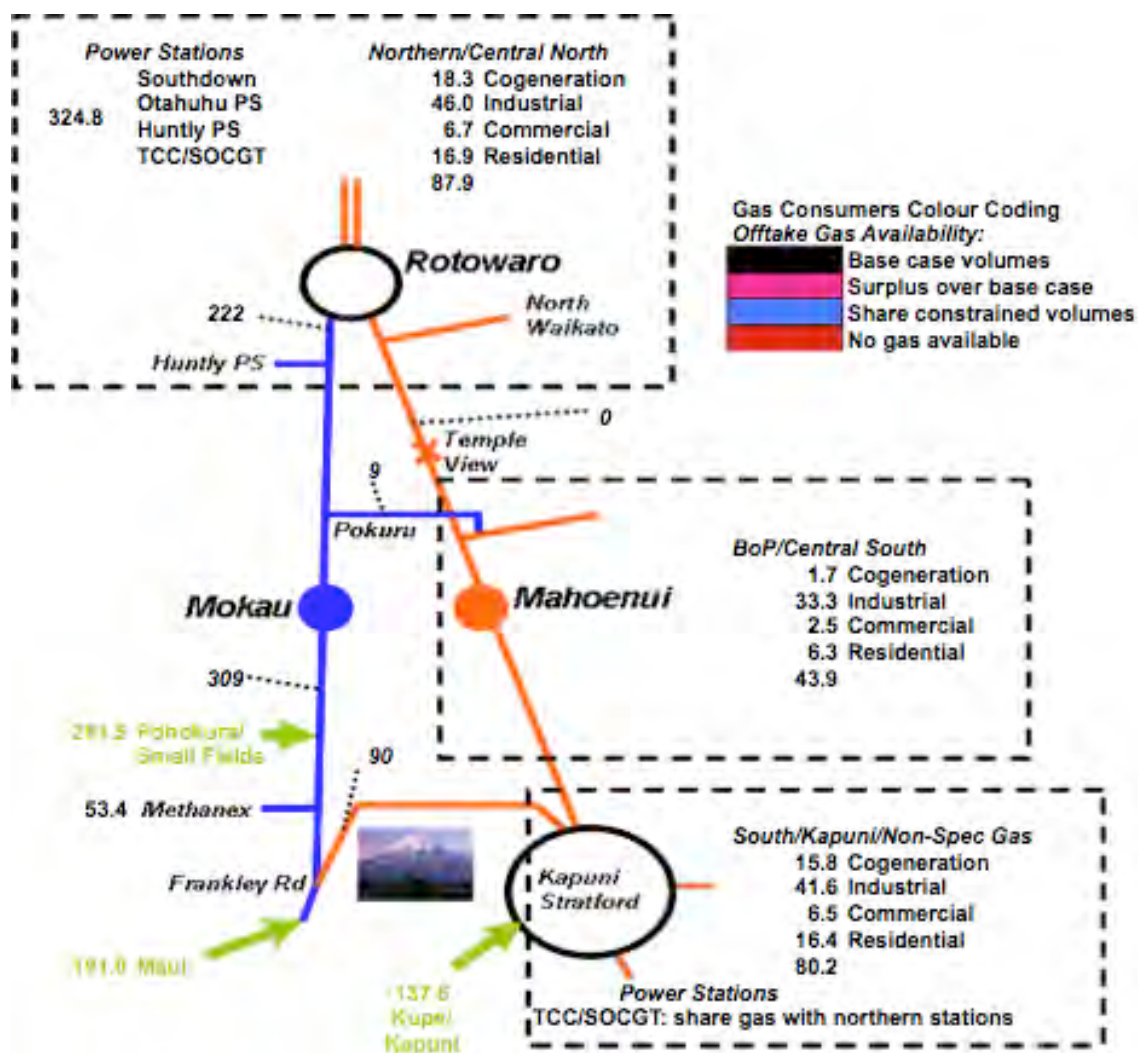


Figure 3: Gas availability for the base case (TJ/day)

Note: Derived data.

- **Maui 191 TJ/day:** the Maui field is in decline and output has been falling for some years from its nominal maximum of 485 TJ/day (see Figure 2). It is possible that some increase could be achieved in an emergency but any significant increase would require subsurface work which would take longer to plan and execute than the duration of any

gas shortfall included in these scenarios. In the longer run, any increase will be offset by the continuing decline in field output.

- **Pohokura 224 TJ/day:** this 2008 maximum is consistent with a nameplate capacity of 210 TJ/day⁷. Pohokura presently is operating through its plateau output phase.
- **Other Fields 37.5 TJ/day:** there is some potential to increase the deliverability of gas from the lesser fields. It is understood that additional production wells will be drilled at Mangahewa later in 2009 and output could be increased quickly at both Turangi and Kowhai. Output from these fields could then be increased to about 60 TJ/day.
- **Kapuni 67.6 TJ/day:** annual Kapuni production is fairly constant although maximum field deliverability has declined: gas reinjection ceased about eight years ago and it is understood there is now some concern about maximum field output. There is potential to increase output through an in-fill drilling programme but this would take at least a year to plan and execute. The maximum deliverability figure used has been prorated from annual production of 23 PJ.
- **Kupe 70 TJ/day:** Kupe will commence production in 2010 at a rate similar to Kapuni's present output

4.2 Contingency Management

In the event of a gas shortfall, supply of gas to consumers is prioritized according to curtailment bands set out in the Gas Governance (Critical Contingency Management) Regulations 2008. These bands are shown in ascending order of priority in Table 3. Note that the Regulations do not apply to residential consumers, as this power is not included in the Gas Act.

This same order of priority is applied when allocating gas in the shortfall scenarios. Except for the readily identifiable large industrial users, the industrial and commercial sectors present the most difficulty in allocating gas users between the different curtailment bands using information in the public domain. Based on industrial and commercial consumer numbers and consumption in the Energy Data File, the following assumptions have been used:

- **Curtailment Bands 1a and 1b:** the major gas fired power stations (Otahuhu, Huntly, TCC and the Southdown co-generation plant) plus Methanex.
- **Curtailment Bands 2 and 3:** all the noted industrial users (Fonterra, smaller co-generation plants, CHH, NZ Steel, NZRC, Peroxide plant, and other dairy factories) plus 85% of the residual offtake classified as industrial. The 15 TJ/day threshold applies to individual sites, so will not apply to gas users with a large aggregate consumption over several sites, such as Fonterra and CHH.
- **Curtailment Band 4:** 15% of the residual offtake classified as industrial and 15% of commercial offtake.
- **Curtailment Band 5:** 25% of commercial offtake
- **Curtailment Band 6:** 60% of commercial offtake.

⁷ Todd notes deliverability of 235 TJ/day

Curtailment Band	Consumption	Description
0		Gas for storage.
1a	>15TJ/day	Consumers with alternative fuel capability.
1b	>15TJ/day	Consumers without alternative fuel capability.
2	>10TJ/year	Industrial/commercial consumers with alternative fuel capability.
3	>10TJ/ year	Industrial/commercial consumers without alternative fuel capability
4	2 to 10TJ/ year	All consumers
5	>2TJ/ year	Essential service providers.
6	<2TJ/ year	All remaining consumers (excluding residential ⁸).

Table 3: Gas consumer curtailment bands

4.3 Gas Storage

In addition to the above fields, gas will be available from the Ahuroa gas storage facility, which is presently being filled by Contact to provide gas supply flexibility for its gas-fired power stations. Ahuroa is part of the onshore TAWN gas fields near Stratford and gas can be piped directly to the Stratford power stations, the Vector Frankley Road-Kapuni pipeline or the MDL pipeline at Tikorangi, north of New Plymouth. The working gas storage capacity of the facility is 10 to 15 PJ⁹ and the maximum output understood to be in the order of 100 TJ/day¹⁰.

⁸ Whilst the Regulations exclude residential consumers, they can be curtailed on safety grounds so as to prevent a pressure collapse in a gas distribution network.

⁹ Contact Energy annual report 2008

¹⁰ Oil and Gas Journal, January 2009. This probably assumes expansion of the existing gas processing plant, as the stored gas must be dried when extracted. The current capacity of the drying plant at TAWN is about 25 TJ/day.

5. Consumer Response to Gas Shortfall

With the exception of the gas-fired power stations, all gas consumers use a combination of gas and electricity. The very large majority of consumers purchase all of their electricity from the grid, although some of the largest industrial consumers generate some of their own electricity requirements on-site using gas, coal or waste products from processing. This section examines the response of consumers to shortfalls in gas availability, in particular any concurrent change in demand for electricity.

Some of the major industrial gas users were contacted directly to discuss any contingency plan they might have to a counter gas shortfall. To assess the responses of smaller consumers, three consulting engineering companies with extensive experience in providing energy services to industrial and commercial users were contacted. It is evident from the responses received that any contingency plans were strongly influenced by the very high level of reliability provided by the New Zealand gas industry.

5.1 Major Industries

Petrochemicals Production

Petrochemicals production at Methanex's methanol plants, ammonia-urea at Ballance, and at a much smaller scale at the peroxide plant, differs from other gas consumers in that the gas input provides both energy and the material to produce the chemical products. Without the gas feedstock, the plants cannot operate.

Electricity load from the grid will reduce when gas is not available to the plant, although over a short period some operations may continue, for example the pumping of methanol stored at the plants to the port of Taranaki for export. Table 2 shows the reduction in grid electricity requirements from the Methanex and Ballance plants.

Since the expiry of the original Maui gas sales contracts, under which the methanol plants had a gas entitlement, Methanex has tended to operate as a swing consumer of gas, taking available gas when it was attractively priced relative to the export price of methanol. Because of their large gas use, these plants are in the same curtailment band as the major power stations.

	Methanex: Motonui	Methanex: Waitara	Ballance
Load During Production	4 MW	2 MW	4 MW
Load Reduction: short term	1.5 MW	1.0 MW	
Load Reduction: long term	3.5 MW	1.5 MW	4 MW

Table 4: Reduction in grid electricity load at major petrochemical plants

Carter Holt Harvey

CHH is a major consumer of gas and electricity, principally at its Kinleith paper mill where gas (3-4 PJ pa) is used for co-generation and steam-raising. About half the mill's electricity load (approximately 70 MW) is generated on-site. Its Kawerau mill also uses gas but primarily in its lime plant. The principal source of energy at both plants is waste from wood and the processing plants, and geothermal energy at Kawerau. However both plants could not operate without gas and CHH does not have a contingency plan to operate without it.

In the event of gas unavailability, demand for grid electricity at both Kinleith and Kawerau would cease. This is estimated to be 38 MW and 10 MW respectively. As both mills are located on Vector's Bay of Plenty pipeline, they would both be affected if gas availability to that pipeline were curtailed.

CHH has other sawmilling and wood products operations using gas but these are dispersed and use relatively small quantities of gas.

The other major pulp mills in New Zealand are not based on the thermal energy intensive Kraft process and so are not dependent on gas supply.

New Zealand Steel

In addition to its large requirement for coal, New Zealand Steel consumes about 2.2 PJ of gas annually and has an electricity load of 110 to 120 MW which is imported from the grid. Electricity imported is offset by on-site generation using waste gases from the iron-making process, which exports 60 MW from the site and which can be complemented by a further 10 MW of gas-fired generation. The majority of the electricity used is in the iron melters.

Gas is used at the plant for heating the ladles feeding the steel-making process and in a variety of other applications such as hot rolling, painting ovens, annealing and metal coating. A gas shortfall would severely limit the operations of the mill and with an extended outage would cause it to virtually cease operations.

It is possible that some parts of the plant could continue for some limited time without gas, notably the iron plant which fuels on-site generation. The steel plant cannot operate without gas and, as it is the major consumer of electricity at the site, there is a possibility that some net electricity could be exported from the site during this period. However, NZS do not have a contingency plan specifically to deal with an extended gas outage, the duration and size of this electricity availability is uncertain.

In the event of a complete shut down of the mill, it would cease to draw on the net 53 MW it takes from the grid.

New Zealand Refining Company

NZRC uses about 2 PJ pa of gas for fuel at its Marsden Point oil refinery. A gas shortage would not result in the operations of the refinery being significantly compromised as there are alternative sources of fuel within the refinery streams and would therefore fall within Curtailment Band 2 of the Critical Contingency plan.

Fonterra/Dairy Industry

Gas is the principal source of energy for dairy factories in the North Island. Fonterra has factories located on each of Vector's transmission systems but with particular concentrations on the Bay of Plenty and Central (North) systems and at the Whareroa plant near Hawera. In all, Fonterra uses gas at about 14 locations.

Gas is used in a variety of applications, reflecting the complex range of processing activities carried out in the factories and includes co-generation, steam-raising and drying operations. Plant tends to be relatively large by New Zealand industrial standards with boilers in the 10 to 50 MW_{th} range and operate to a seasonal pattern with high output during the spring and summer milking season and annual boiler plant load factors reported to be less than 40%. The Vector disclosure data indicate that the maximum gas offtake at each factory is typically in the range of 1 to 3 TJ/day, or less than 1 PJ per year. However, offtakes are higher at locations such as Te Rapa, Edgecumbe and Whareroa where there is significant co-generation capacity.

In 2004, Fonterra consumed some 18.1 PJ of gas (approximately 1.8:1 for co-generation and heat) and 6.3 PJ of coal. Co-generation at the dairy factories produced about 1,300 GWh of electricity of which 940 GWh was used on-site, the remainder being sent to the grid. A further 640 GWh of electricity was imported from the grid to its factories¹¹. Some significant changes have been made to the Fonterra's energy use patterns, notably expansion of South Island dairying and the closure of the Te Awamutu co-generation facility but details of these changes have not been made available. Fonterra has indicated a gas shortfall would have significant impact on its operations.

Using the above data as a measure of relative electricity and gas consumptions, and assuming that all electricity from the cogeneration plants is initially sent to the grid:

- When gas is not supplied to the cogeneration plants no electricity will be sent to the grid.
- When no gas is available for other uses at the Fonterra factories, grid electricity requirements (including that which is generated at the Fonterra factories) are reduced by about 0.4 TJ electricity/TJ gas. This allows for some residual use of electricity at these sites.

In the scenarios where gas supplies are closed off to the dairy factories north of Taranaki, the reduction in gas supply is 27 TJ/day (net of gas used in the co-generation plants). This equates to a reduction in electricity taken from the grid of 123 MW, from which must be deducted the 52 MW combined capacity of the Te Rapa and Edgecumbe¹² co-generation plants which will cease to operate, resulting in a net reduction in electricity demand of 71 MW.

¹¹ "Heavy Industry Energy Demand", Covec, June 2006. Fonterra did not respond to a request for data.

¹² Whareroa will continue to operate in all scenarios. Te Awamutu has ceased to operate

5.2 Light Industrial and Commercial Sectors

Gas is used in a wide variety of applications in the industrial and commercial sectors, some, such as water heating and steam-raising, simply utilise gas's thermal energy whilst others, such as direct drying and heating, utilize gas's very clean combustion properties.

Consumers can cater for a gas shortfall by either having standby plant, such as a coal fired boiler, or the ability to switch fuel, e.g. diesel in boiler plant or LPG for direct heating. However, the very large majority of light industrial and commercial gas users have not catered for such a contingency due to the high cost of installing standby or switching facilities and the historically very high reliability of gas supply¹³. In practice, standby plant often is old plant previously replaced by gas plant, such as an old coal fired boiler.

The likely reaction of these sectors to an extended gas shortfall is not certain as there is no such experience in New Zealand¹⁴ nor have any relevant consumer surveys been undertaken¹⁵. Two incidents in Australia provide some insight into the impact of a gas shortage on industrial and commercial activities:

Western Australia 2008: Production stopped at a Western Australian plant processing about one third of the state's gas requirements in early June 2008 and was partially resumed in late August with 85% of full output restored by December. The Chamber of Commerce of Western Australia reported in its subsequent survey of businesses:

- *"nearly half of all respondents have been affected in some way by the natural gas outage. Some 16.6 percent of respondents indicated that their business had been directly affected by the outage, while a further 33.2 percent had been indirectly affected. Of those businesses impacted by the gas outage, their production declined by an average 30.6 percent.*
- *Businesses operating in the manufacturing industry were hit hardest by the supply shortfall, with nearly 62 percent of manufacturing respondents affected in some way by the natural gas outage. Over 27 percent of respondents from the manufacturing sector had been directly affected, while a further 34.5 percent reported to be indirectly affected by the gas crisis. Of affected manufacturing businesses, production declined by an average of 45 percent.*
- *Overall, respondents were generally unable to change between energy sources or switch production times in order to mitigate the impact of the gas shortage.*
- *Respondents' ability to reduce their consumption of energy was also very limited, with 62 percent of respondents unable to cut consumption.*
- *Similarly, the majority of respondents were unable to shift their production to non-peak energy."*

¹³ Personal communication: industrial and commercial gas plant consulting engineers at BCHF, MWH and Maunsell.

¹⁴ The failure of the Hawkes Bay pipeline in 19.. was for one week only.

¹⁵ Personal conversation with EECA: No such survey would appear to have been undertaken in New Zealand.

Victoria 1998: A similar pattern was observed in the 1998 gas supply failure in Victoria, Australia. A fire at the Longford gas processing plant on 25 September cut off virtually all supplies to Victoria's gas market until the complete restoration of supply on 14 October:

*"To prevent a complete run-down of reserves, dwindling supplies of gas were prioritised to essential services only, such as hospitals. About 1.3 million households and 89,000 businesses were affected by the disaster and export earnings alone were cut by over \$200 million. Stand-downs and production losses for affected Victorian and interstate businesses and factories were initially estimated by the Victorian Employer's Chamber of Commerce and Industry to cost up to a billion dollars (ABC Online 5/8/1998). This figure was later revised to \$1.3 billion as reported by the Financial Review, 27/4/99 (and other sources)."*¹⁶

There is no similar long-term example in the New Zealand market although it should be expected that similar disruptions would occur in the industrial and commercial sectors. The impact is likely to be less in essential services such as hospitals as standby facilities are more common and they are afforded greater priority in the Critical Contingency Regulations.

However the longer a gas shortfall persists, the more probable it will be that manufacturers and businesses will find ways of continuing their activities as energy costs in these sectors, although significant, tend not to dominate total operating costs. Obvious examples of remedial action are the installation of diesel burners in gas-fired boilers, using LPG burners for cooking and other forms of direct heating, and the use of electricity for heating. Uptake of alternative fuels could be restrained by increased demand for the necessary combustion and fuel storage equipment, some of which would have to be imported. Furthermore, there will also be pressure on the fuel supply industry to provide the additional quantities of fuel required. The LPG industry could be particularly affected because of the relatively small scale of the industry, the high costs of the storage equipment necessary, and lead-time to obtain resource consents.

Without empirical evidence, it is difficult to estimate the change in electricity consumption associated with an extended gas shortfall, partly because of the uncertain consumer response and partly because of the wide variety of energy use patterns and applications at industrial and commercial sites. Responses at individual sites could range from:

- an uptake in electricity use if gas is replaced by electricity
- no change if gas is replaced by another fuel such as LPG, diesel or coal ; to
- a decline if plants curtail activities.

Maximum gas consumption in the light industrial and commercial sectors as estimated from the pipeline disclosure information is 44 TJ/day and 16 TJ/day. In the two scenarios where gas supply to these sectors is curtailed by the complete closure of the MDL pipeline, these are reduced to 20 TJ/day and 15 TJ/day, a reduction of 24 TJ/day, equivalent to some 280 MW. This represents the outer bound of possible increased electricity consumption, i.e. if all gas in these sectors is replaced by electricity. Whilst this places the potential for increased electricity demand in perspective, in reality it greatly over-states this potential as it will be technically impractical to replace gas with electricity in many instances, other fuels such as LPG and diesel

¹⁶ Emergency Management Australia Disasters Database

will be more cost effective replacements in others and some businesses will curtail or cease operations. In the absence of any corroborating empirical evidence, it is improbable that this increased demand will be more than 40 MW and is more likely to be lower or possibly negative. Furthermore, the increase will not be instantaneous but will increase over a number of months.

For the purpose of this study, it is assumed that overall electricity demand in these sectors will increase by 40 MW, providing a conservative bias on electricity generation requirements. As gas consumption typically is larger at industrial sites and these sites are more likely to be curtailed, 39 MW of this increase is assumed to occur in the industrial sector and 1 MW in the commercial sector.

5.3 Residential

Under the scenarios examined there is no reduction in gas supply to this sector as there is always sufficient gas to supply the whole of the sector. In practice, residential consumers are usually the last category to be curtailed and are not included in the gas contingency regulations.

However, it is worth noting that:

- Should there be a complete outage of gas (through the simultaneous failure of both the MDL and Vector pipelines north of Taranaki or one of the Vector spur lines) there is potential for significant uptake of electricity by the residential sector in the areas affected. EECA estimates that residential gas consumption is split 45% in water heating, 41% space heating and 14% cooking. Technologies exist to switch each of these to electricity, LPG or solid fuels and in the event of a gas shortage most households would adapt to maintain these household functions.
- Residential gas consumption is only 12% that of electricity¹⁷.

¹⁷ When the gas failure to the Hawkes Bay occurred, the residential sector could be supplied by gas stored as line-pack but only for about a week.

6. Electricity Generation

Gas-fired plant has contributed some 20% to 25% of annual electricity generation over the past ten years and provides a reliable complement to generation from renewable resources which are subject to the uncertainties of rainfall and wind conditions. A significant disruption to the supply of natural gas will impact on the generation of electricity in New Zealand.

Most electricity produced from gas is generated at the combined cycle plants at Otahuhu, Huntly and Taranaki, with lesser quantities generated at the Southdown combined heat and power plant and the proposed open cycle gas turbine at Stratford. In the past, large amounts of gas were also burnt by the four steam turbine units at Huntly. These stations are complemented by smaller gas-fired cogeneration plants situated at industrial sites at Kawerau, Kinleith and Glenbrook and at the Kapuni gas production station.

Plant	Installed Capacity (MW)	Heat Rate (GJ/MWh)	Maximum Gas Consumption (TJ/day)
Otahuhu B	385	7.05	65.1
Huntly U5 (e3p)	400	7.08	68.0
Huntly U6	45	9.50	10.3
Southdown	190	10.00	45.6
Taranaki CC	398	7.30	69.6
Stratford CT	200	8.90	42.7

Table 5: Major gas fired power stations

Electricity generation consumed 85 PJ of gas in 2007 or an average of 232 TJ/day, lower than the combined maximum weekly offtakes of the power stations as reported in the MDL and Vector disclosure documents¹⁸, the difference between averages and maxima reflecting variations in plant output as electricity generation matches seasonal and daily fluctuations in demand. The analysis of gas deliverability in Section 4 indicates that there is sufficient gas and pipeline capacity available to meet the combined maximum gas consumption of these six

¹⁸ The power station maximum weekly offtakes in the MDL and Vector disclosure documents are similar to those listed in Table 5. Over 40% of gas consumed in electricity generation during 2007 was at the 1000 MW Huntly steam turbine power station. In the analysis below it is assumed that this plant will burn only coal in the future now that the Huntly e3p CCGT plant is operational. Hence the maximum gas usage in the scenarios is lower than the 2007 usage.

stations¹⁹, although this may not necessarily hold in the future as the deliverability of gas fields is not constant over time.

The impact of gas shortages on the generation of electricity is assessed in this study using the Stochastic Dual Dynamic Programming optimal dispatch model. Power system data was obtained from the Electricity Commission's 2008 Statement of Opportunities, modified by publicly available information regarding more recent developments. The model investigates a two-year period from January 2010 to December 2011 with the gas outage assumed to start on 1 April 2010 (week 14/2010 in the figures below), a time when demand for electricity starts to climb with the approach of winter and lake levels typically are high in preparation for winter. Plants listed in the above table are assumed to be dispatchable up to the limits of available fuel supply, but with the assumption of some planned outages for maintenance. Cogeneration plant output is based on historic output except where gas is not available to this category of consumer. Southdown is assigned higher priority when gas supplies are constrained but with limited availability based on a number of years of actual generation.

The scheduling of power stations is determined on a least-cost basis, with details of the pricing and cost assumptions used in each scenario shown in Appendix 1. Base case generation of electricity and gas consumption at the six gas-fired plants over the two year period modeled is shown in Figure 4²⁰.

The average gas consumption at the six power stations in the base case over the two-year period is 152 TJ/day with a maximum weekly average of 201 TJ/day. Whilst this does not account for intra-week peaks in gas demand, the base case demand for gas at these stations is significantly below the quantity of gas available for electricity generation.

In the analysis of the different gas availability scenarios, particular attention is paid to:

- **Generation mix.** Disruptions to gas supplies will have localised effects, impacting on the availability of gas to some power stations but not others. For example, a constraint in the MDL pipeline north of Taranaki will reduce gas availability to the Huntly, Otahuhu and Southdown power stations but will not constrain supplies to the TCC or Stratford OCGT stations as these are supplied through the Vector system. Generation output will shift from the northern to the southern gas-fired stations or other sources of generation.
- **Coal fired generation.** In the base case the 1000 MW Huntly coal-fired station consumes about 1 million tonnes of coal per annum at an average station utilization of 29%. This station represents relatively cheap²¹ available capacity near major population centres to replace constrained gas-fired stations.
- **Energy storage.** The replacement of constrained gas-fired plant not only requires alternative available generating capacity but stored energy to power these plants. This stored energy is in the form of water in hydro reservoirs in the North and South Island river systems, the coal stockpile at Huntly and the gas storage facility at Ahuroa. It is assumed that the Huntly stockpile is 707,000 tonnes at the end of 2008 with transport

¹⁹ The base case assumes 325 TJ/day of gas is available for electricity generation at these six stations compared with a maximum combined off take of 301 TJ/day. Kupe gas is available and the Rodney power station is not operational.

²⁰ It does not include Huntly U6 which averages 1.6MW over the two year period with a maximum of 6.8MW

²¹ Coal is priced at \$4.00/GJ and gas at \$5.50/GJ

infrastructure in place to deliver up to 2.4 million tonnes coal throughout the year. The Ahuroa gas storage facility has 10 PJ of gas available that can be delivered at up to 100 TJ/day. Gas from this storage is priced \$2.00/GJ higher than other gas.

- **Generation Deficit.** The deficit between electricity demand and generation arising from the gas shortfall is determined to contextualize any action the electricity industry must take to manage demand.

Base Case: Average Weekly Gas Generation

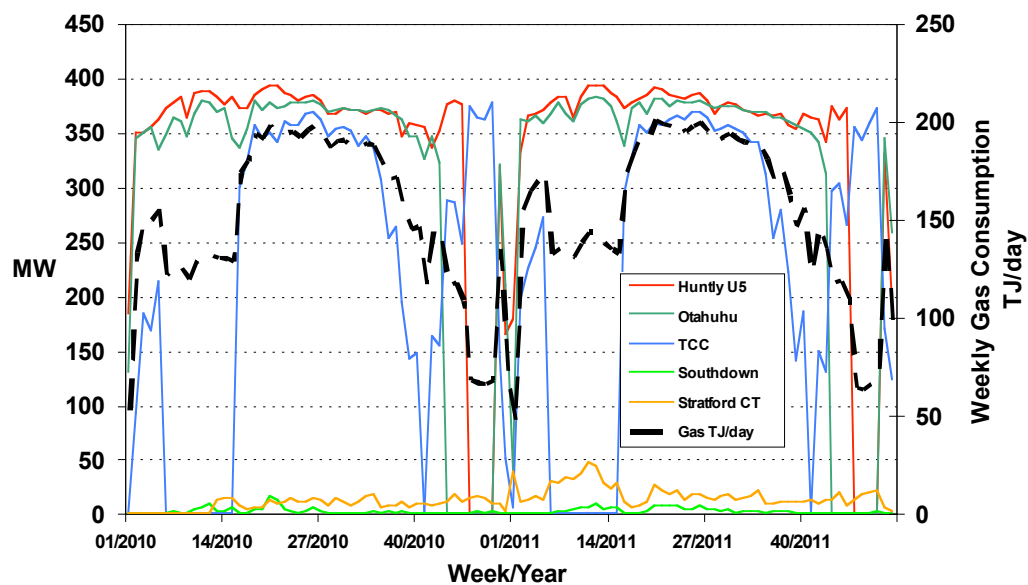


Figure 4: Base case for average weekly gas generation

7. Major Disaster in Taranaki Area

Scenario Event: volcanic eruption to north-west of Mt Taranaki

7.1 Background

Mt Taranaki last erupted about 200 years ago at the culmination of eight eruptions in the preceding 300 years²². Egmont Volcano is of the "slumbering" type that could begin renewed activity in the next 100 years. One of the characteristic features in the history of Egmont Volcano has been the irregular occurrence of enormous landslides. On three occasions, twice within a very short period of geological time, former Egmont cones have collapsed to the northeast, southeast and west. In each instance extremely large volumes of material greater than 3.5 km³ flowed across the landscape to travel over 40 km distance, reaching the present Taranaki coastline.

The combination of a massive landslide, volcanic ash and earthquakes that could be associated with a volcanic eruption could cause wide spread disruption to the gas production and transmission infrastructure. While the Maui pipeline has no above-ground sections near Mt Taranaki, land slides and river bed scouring could stress the pipeline to failure in multiple locations and destroy above ground valve stations. The pipeline could not be returned to service until its integrity was re-established.

Several production plants could be affected, and potentially destroyed by a massive landslide. Earthquake damage, ash and other air-borne debris could cause outages for several months while damaged equipment is repaired or replaced.

7.2 Damage to gas system

- Pohokura/small Taranaki fields: production and gas processing facilities damaged: not re-instated before 1 year
- Methanex damaged: not re-instated before 1 year
- Damage and major slips at MDL and Vector pipelines at Frankley Road-Kapuni and Pohokura injection points: re-instated after 3 months

²² <http://www.gns.cri.nz/what/earthact/volcanoes/nzvolcanoes/egmontprint.htm>

7.3 Impact on Gas Operations

7.3.1 First Three Months

- No deliveries from MDL pipeline into Vector system at Frankley Road, Pokuru or Rotowaro
- Gas delivery north of Kapuni limited by capacity of the 200 mm Vector Central (South) pipeline (33 TJ/day). The Temple View valve is opened to allow gas to flow north through Rotowaro.
- Consumers north of Kapuni subject to gas contingency priorities: power stations and large industrial consumers lose gas supplies, supplies limited to essential services and residential users plus some smaller light industrial and commercial users on Vector Central (South), Central (North), Bay of Plenty and Northern Systems.
- Consumers south of Kapuni including Ballance, Whareroa and all consumers on the Vector South system can be supplied in full from Kapuni and Kupe.
- TCC and Stratford OCGT remain operable but have restricted gas supply from the Kupe and Kapuni fields.

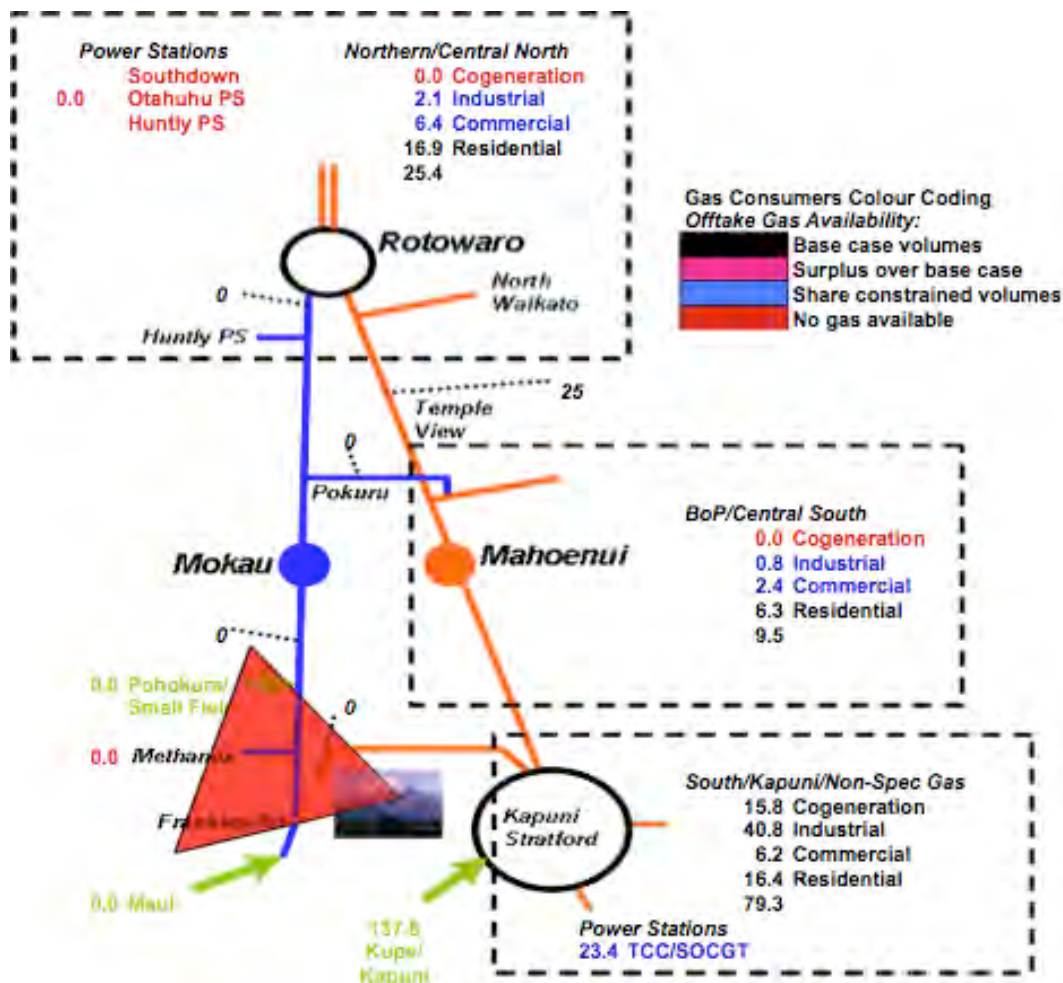


Figure 5: Taranaki Disaster: Gas Availability first 3 months (TJ/day)

7.3.2 Three months to One Year

- MDL and Frankley Road-Kapuni pipelines reinstated, Vector Central (South) pipeline no longer a constraint on northwards gas flow
- No gas supplies available from Pohokura and smaller fields
- Methanex remains inoperable
- Gas supplies can be re-instated to all other industrial and commercial gas users.
- Limited gas is available to TCC, Stratford OCGT, Huntly, Otahuhu and Southdown power stations but full capacity constrained by continued unavailability of gas from Pohokura and the smaller onshore fields.

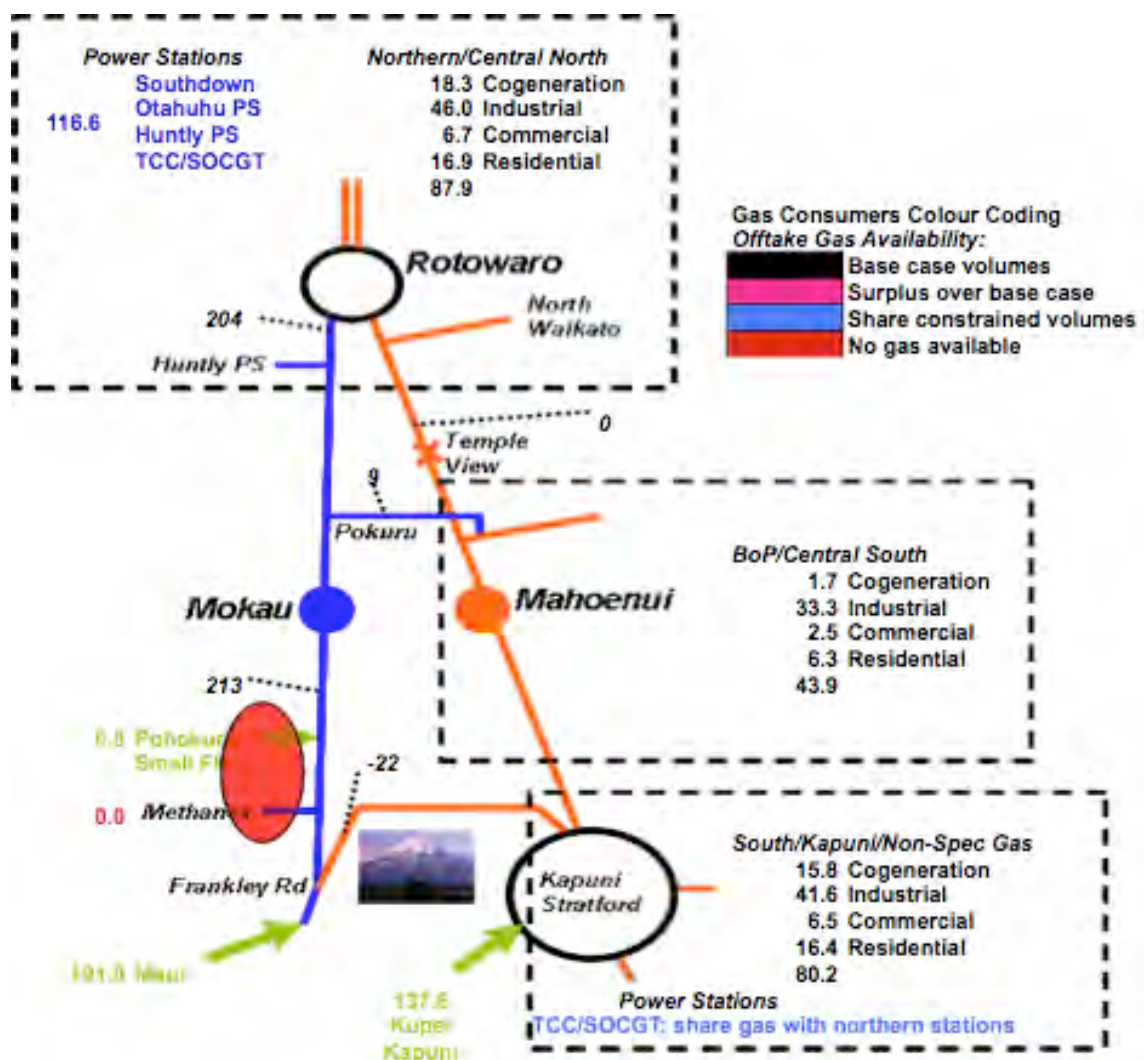


Figure 6: Taranaki Disaster: Gas Availability 3 months to 1 Year (TJ/day)

7.4 Impact on Electricity Generation

7.4.1 Generation Mix

The reduction in output from the gas power stations is taken up principally by the Huntly coal-fired plant and to a lesser extent by hydro generation. This is particularly the case during the first three months of the scenario as illustrated in Figure 7. During this period demand for electricity will reduce at industrial plants forced to close or limit their activities because of the gas shortage. It is estimated that this reduction in electricity demand is equivalent to about one third of the concurrent reduction in gas-fired electricity generation.

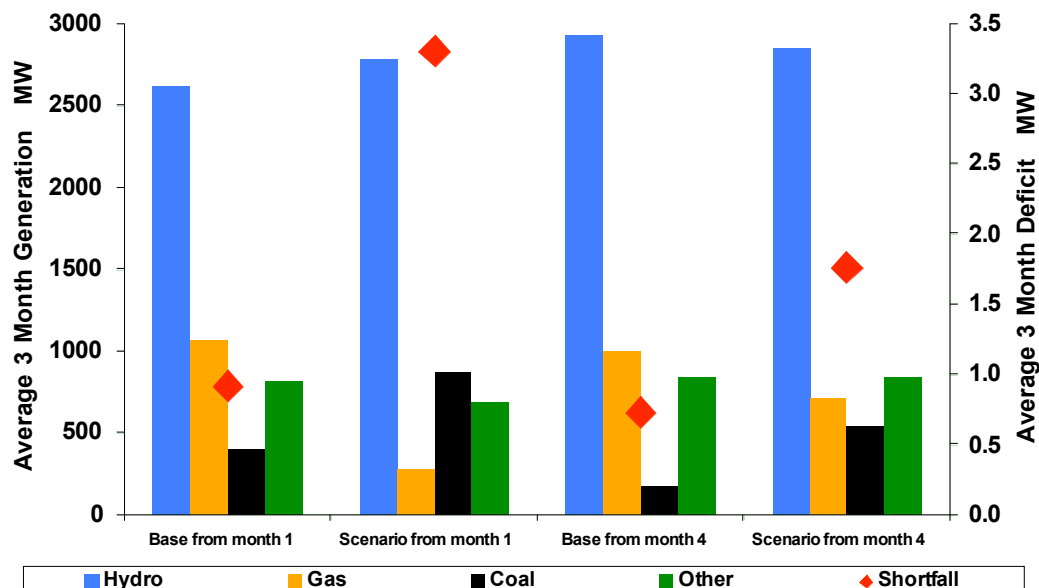


Figure 7: Taranaki Disaster: Generation Mix

Coal consumption at Huntly increases considerably for the first three months and, whilst declining, continues above base case consumption through to the end of the gas shortage, in part because coal displaces some hydro generation during the latter nine months. During the full twelve month period of the shortage average coal consumption doubles from the base case 1 million tonnes to 2 million tonnes per annum, the differential being illustrated in Figure 8. During the first three months of the gas shortage, the rate of coal consumption increases to an annual rate of 3.5 million tonnes of coal, equivalent to an average of 90% plant utilization over this period.

Figure 8 also shows that the gas available for generation is fully utilized during the gas outage except at the New Year where the available gas would not have been taken up in the base case. During the first three months gas is only available to the two southern plants whereas the northern plants take all the available gas for most of the time through to the resumption of full gas supplies when the pattern of generation under the base case is resumed.

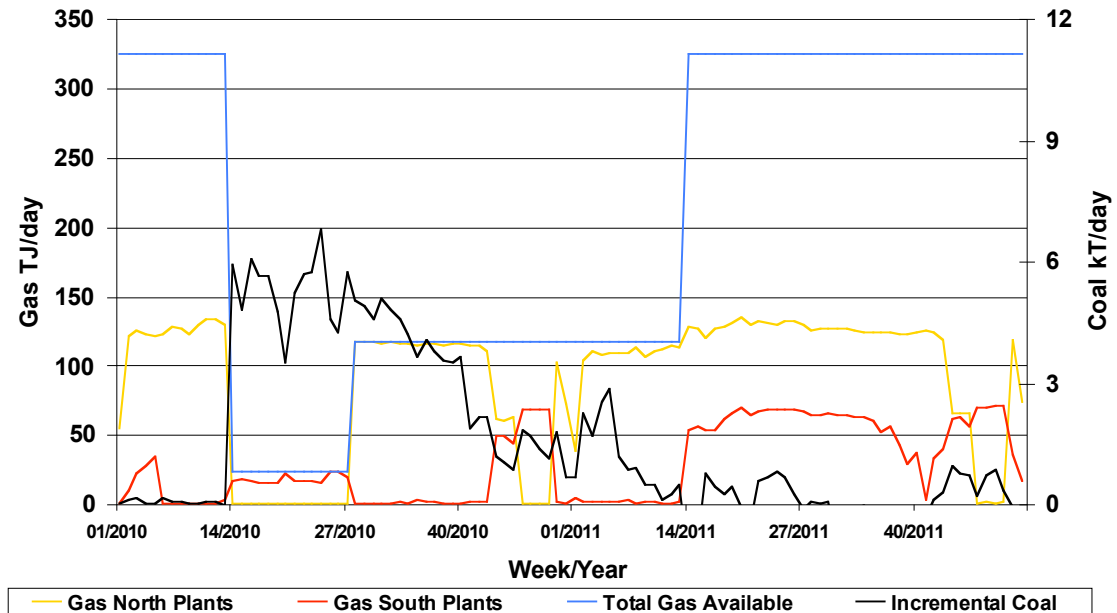


Figure 8: Taranaki Disaster: Gas and Coal Usage

Gas North Plants: Huntly, Otahuhu, Southdown

Gas South Plants: TCC, Stratford OCGT

7.4.2 Generation Deficit

The potential for a deficit between generation output and demand will increase with a shortage of gas. The model predicts the deficit will average 3.5 MW during the first three months of the shortage, peaking at about 18 MW during the later weeks, and will fall thereafter. This level of deficit can be managed by the electricity industry without resort to involuntary load shedding.

7.4.3 Energy Storage

The availability of sufficient energy storage is important in this scenario. As noted the coal-fired Huntly power station takes up most of the generation shortfall and during the first three months consumes coal at a greater rate than is likely to be delivered to the station, even when not taking account of the lead-time necessary to arrange additional supplies. Hydro reserves are reduced in the short term as hydro storage takes up some of the earlier gas shortfall but not to an unmanageable level. In the longer term hydro reserves are not adversely affected as, in the latter part of the gas shortage, coal generation takes up some of the base case hydro generation, effectively increasing the hydro reserves, as shown in figure 9.

With the extended constraint on production from the natural gas fields, the electricity generators draw on the Ahuroa gas storage in this scenario. Drawdown from storage is highly dependent on hydro inflow conditions. On average, nearly 4.5 PJ is drawn from the facility over the twelve month gas shortage, but one inflow scenario draws 11.6 PJ over the period.

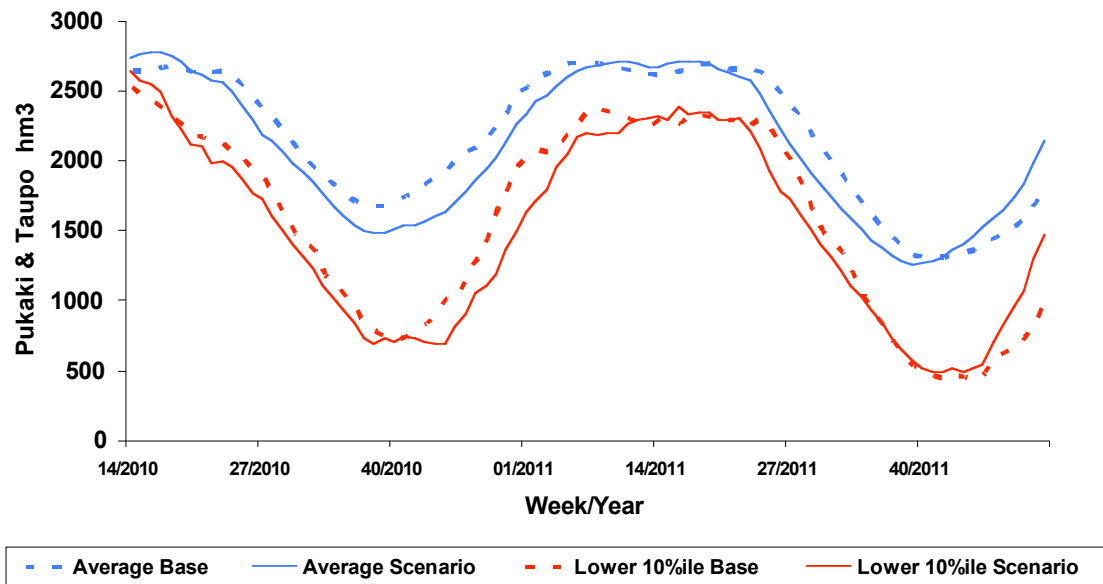


Figure 9: Taranaki Disaster: Effect on Hydro Storage

8. Limited Gas Supply North of Taranaki

Scenario Event: Fire at Mokau compressor station

8.1 Background

The Mokau compressor station effectively governs the Maui pipeline capacity. The constraint is a combination of the compressor flow and pressure capacity. The pressure needs to be sufficient to provide stored line pack to cope with the intraday variations in demand.

Applying the current daily requirement for line pack and compressor capacity the total supply capacity north of Mokau is up to 330 TJ/day²³. The maximum daily demand that has occurred in the past 2 winters is 322 TJ.

The Mokau compressor station has 2x100% gas turbine driven compressors, fitted with CO₂ deluge systems but since the compressors are located in the same compressor house it is conceivable that the combination of a turbine failure, coupled with a failure of the deluge system could result in a fire capable of destroying both units and ancillary equipment.

The compressor station design allows the pipeline to remain in service, bypassing the station. The reduction in capacity depends on what amount of 'spare'²⁴ line pack is required. It is reasonable to expect the amount to be reduced in the event of a long-term Mokau outage, albeit accompanied by stricter controls over pipeline imbalance. Assuming a 50% reduction in the 'spare' line pack, the capacity is reduced to 260 TJ.

Depending on the extent of the damage, a three-month outage to source replacement compressors could be anticipated.

8.2 Damage to gas system:

- Flow north of Taranaki in MDL pipeline limited to into Vector North system reduced to 260 TJ/day for three months.

8.3 Impact on Gas Operations

- Sufficient gas north of Taranaki to supply all industrial, commercial and residential consumers.

²³ As published on OATIS

²⁴ For intraday imbalance and managing emergencies.

- The availability of gas to the Huntly, Otahuhu and Southdown power stations will be limited to a maximum of 163 TJ/day
- Surplus gas available south of Mokau from the Maui, Kupe and Kapuni fields to supply the TCC and Stratford OCGT power stations.
- Sufficient gas south of Mokau to supply all industrial, commercial and residential consumers.

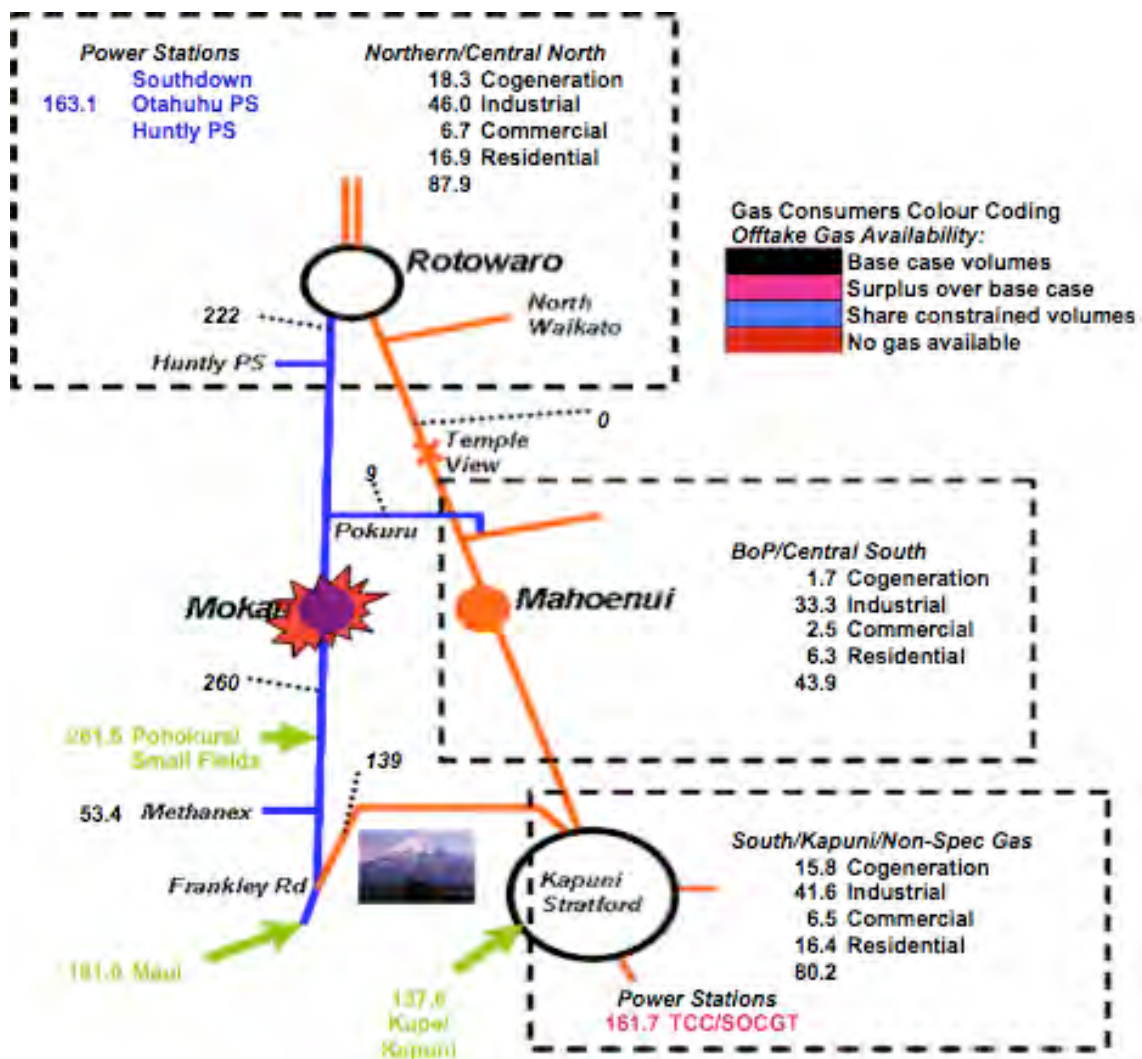


Figure 10: Mokau Fire: Gas Availability (TJ/day)

8.4 Impact on Electricity Generation

The availability of gas to the Huntly, Otahuhu and Southdown power stations will be limited to a maximum of 163 TJ/day but supplies to the TCC and Stratford OCGT power stations and the cogeneration plants will be unaffected.

Electricity generation in this scenario is unaffected as the maximum requirement for gas in the Huntly, Otahuhu and Southdown power stations over the three-month gas shortage period is 135 TJ/day compared to availability 163 TJ/day. Consequently they can operate as if gas supplies are unconstrained. Gas and coal consumption and hydro levels are the same as in the base case.

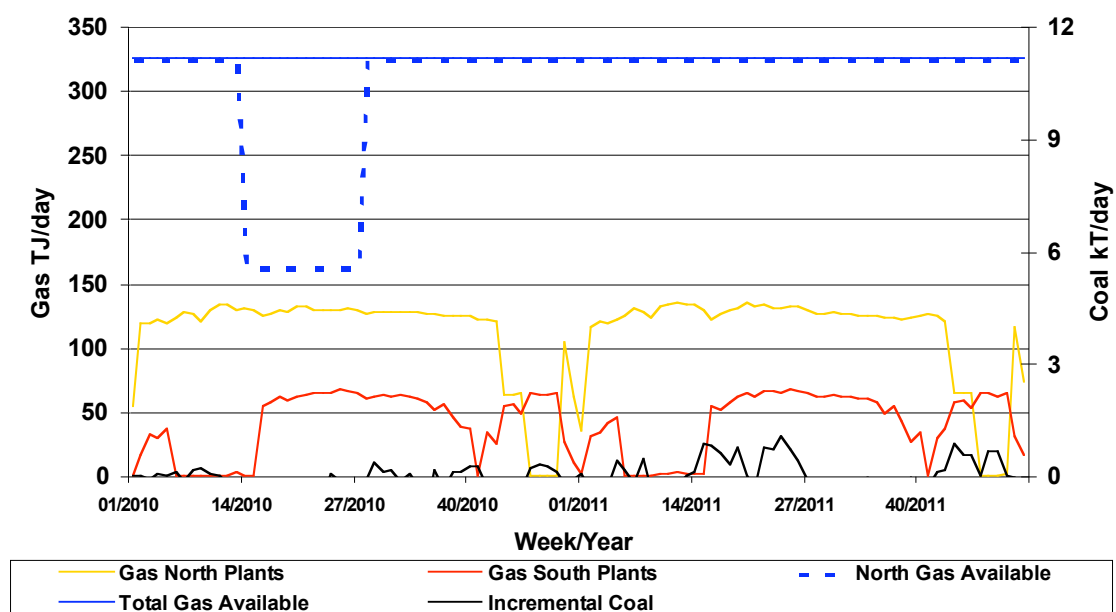


Figure 11: Mokau Fire: Gas and Coal Usage

Gas North Plants: Huntly, Otahuhu, Southdown

Gas South Plants: TCC, Stratford OCGT

9. Limited Gas Supply North of Rotowaro

Scenario Event: Fire at Rotowaro compressor station

9.1 Background

The Rotowaro compressor station boosts the relatively low-pressure gas from the Maui pipeline into the Vector North system, typically boosting the pressure from 45 to 85 barg. With the compressors running at maximum output, the capacity through Rotowaro exceeds 200 TJ/day, but with no compression this drops to around 80 TJ/day. However, if a second pipeline is built to supply the Rodney Power Station, the no-compressor capacity could be doubled.

The Rotowaro compressor station has 2x100% gas turbine driven compressors plus two smaller (pre-Otahuhu B) reciprocating compressors. The compressors are located in two adjacent compressor houses and it is conceivable that the combination of a catastrophic turbine failure could result in a fire capable of rendering inoperable all of the compressor units.

Depending on the extent of the damage, a three-month outage to source replacement compressors could be anticipated.

9.2 Damage to gas system

- Flow north of Rotowaro from MDL pipeline into Vector North system limited to 80 TJ/day for three months²⁵

9.3 Impact on Gas Operations

- Northward gas in Vector Central (South) pipeline constrained at 33 TJ/day, supplying into Central (North) by opening the valve at Temple View. Bay of Plenty can be supplied from MDL pipeline at Pokuru.
- Sufficient gas to supply all industrial, commercial and residential consumers north of Rotowaro.
- Gas supplies constrained to 22 TJ/day for power stations north of Rotowaro: Otahuhu and Southdown.
- Surplus of gas available south of Rotowaro to supply Huntly, TCC and Stratford OCGT power stations and all industrial, commercial and residential users.

²⁵ Should the Rodney power station be constructed, additional pipeline capacity north of Rotowaro would be installed. In this case gas flow north of Rotowaro from the MDL pipeline into the Vector North system would be limited to 160 TJ/day for three months should the Rotowaro compressor station fail.

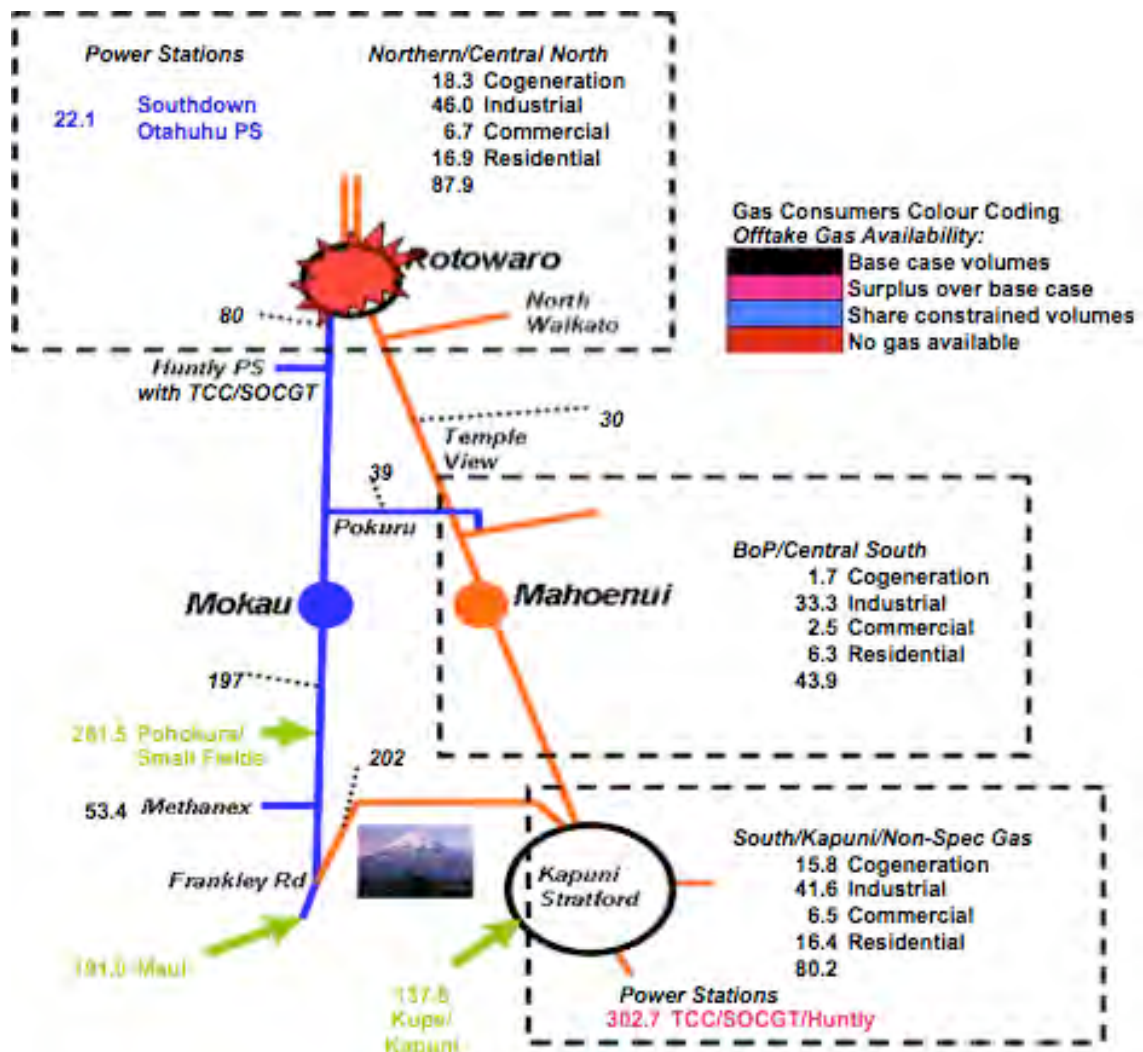


Figure 12: Rotowaro Fire: Gas Availability (TJ/day)

9.4 Impact on Electricity Generation

9.4.1 Generation Mix

Generation at Otahuhu will cease throughout the three-month period as the quantity of gas available north of Rotowaro is insufficient to meet its minimum operating load. Southdown will take a small load but otherwise all gas generation will be at the three stations in the southern group.

Huntly, TCC and Stratford OCGT gas-fired power stations will operate at near the same output as in the base case. The Huntly coal-fired station will take an increasing share of the shortfall in output from Otahuhu over the three-month period of the gas shortage.

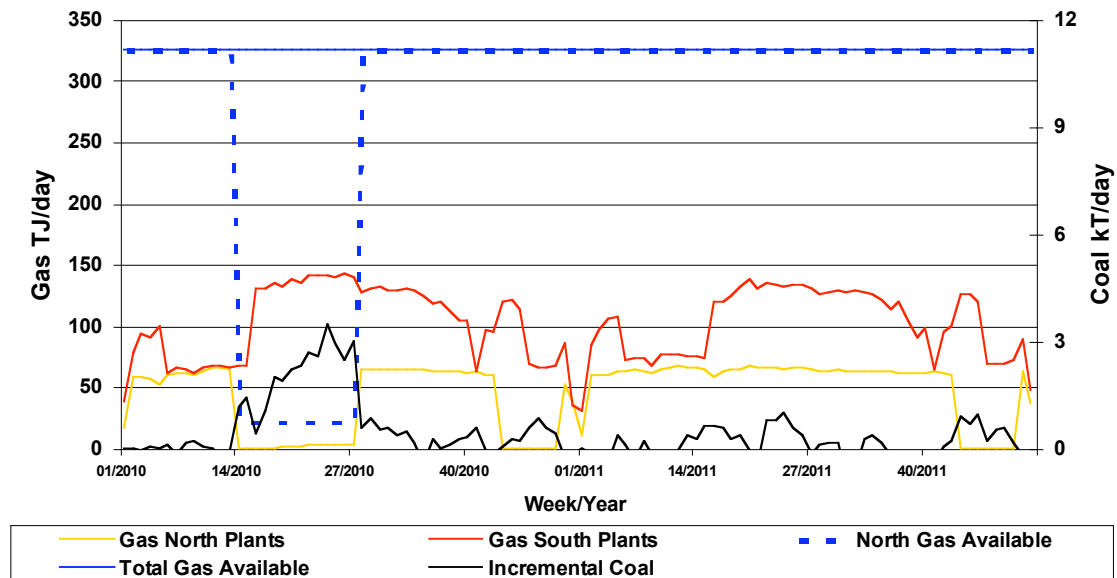


Figure 13: Rotowaro Fire: Gas and Coal Usage

Gas North Plants: Otahuhu, Southdown

Gas South Plants: Huntly, TCC, Stratford OCGT

The average rate of coal consumption at Huntly during the gas shortage will be 2.5 million tonnes per year, peaking for more extreme hydro inflow scenarios to 3 million tonnes per year. Overall, the average coal burn at Huntly will increase by about 250,000 tonnes during the gas shortage.

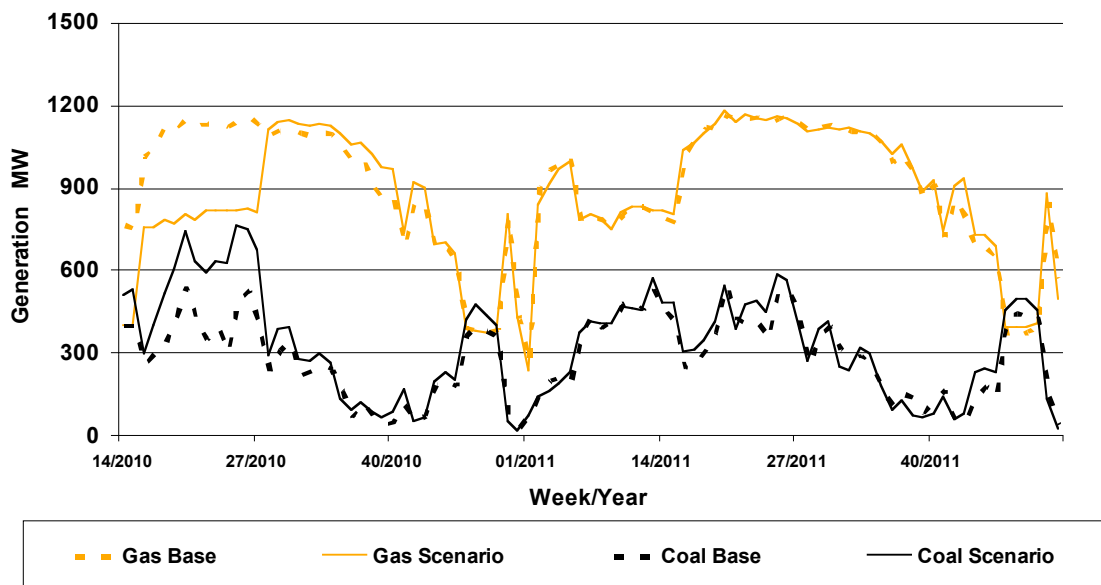


Figure 14: Rotowaro Fire: Electricity Generation Mix

9.4.2 Generation Deficit

The potential for a deficit between generation output and demand is anticipated to be relatively minor in this scenario, peaking at a weekly average of about 5 MW towards the end of the gas shortage.

9.4.3 Energy Storage

This scenario demonstrates the importance adequate reserves of energy storage to offset the impact of a gas shortage on electricity generation. In particular, the availability of spare capacity and coal stockpile at the Huntly power station will play a major role in providing back-up generation. Utilisation of the Ahuroa gas storage facility is not predicted in this scenario as there is surplus gas available for the southern group of power stations, which it would otherwise supply.

Hydro storage levels are predicted to fall relative to the base case in the early part of the gas shortfall but the relativity will stabilize as coal-fired generation takes up a greater share of lost gas-fired capacity towards the end of the shortfall.

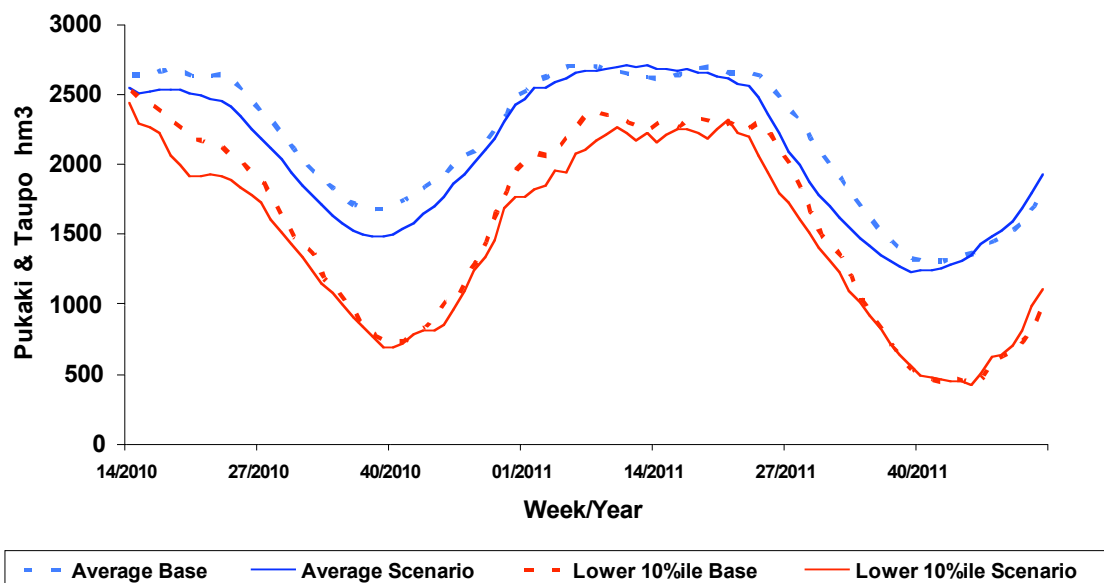


Figure 15: Rotowaro Fire: Effect on Hydro Storage

10. Disruption to MDL Pipeline Operation

Scenario Event: Landslip damage to MDL pipeline. The length of damaged pipe exceeds the spare pipe held in NZ so pipe must be sourced overseas, delaying the repair.

10.1 Background

The pipeline route through north Taranaki includes areas prone to coastal erosion and areas prone to landslips. While pipelines are remarkably resilient, pipeline failures due to large earth movements do occur and in the 1970's a large land slip in Taranaki resulted in the rupture of the 200 mm Vector pipeline. Although pipeline ruptures can typically be repaired in a few days, a large land slip may require the pipeline route to be diverted, which could require several hundred metres of pipe, which would need to be shipped in from overseas²⁶.

10.2 Damage to gas system

- Flow north of Taranaki from MDL pipeline stopped for 2 weeks to 1 month

10.3 Impact on Gas Operations

- No deliveries from MDL pipeline into Vector system at Pokuru or Rotowaro
- Gas delivery north of Kapuni limited by capacity of Vector Central (South) pipeline (33 TJ/day). The Temple View valve is opened to allow gas to flow north through Rotowaro.
- Consumers north of Kapuni subject to gas contingency priorities: power stations (Huntly, Otahuhu and Southdown), cogeneration plants and large industrial consumers lose gas supplies. Supplies limited to essential services and residential users plus some smaller light industrial and commercial users on Vector Central (South), Central (North), Bay of Plenty and Northern Systems.
- Surplus of gas available south of slip location to supply power stations, cogeneration, and all industrial, commercial and residential consumers south of Kapuni including Ballance, Whareroa and all consumers on the Vector South system. TCC and Stratford OCGT have unconstrained supplies of gas.

²⁶ Sufficient spare pipe and fittings are held to deal with a short length of damaged pipeline. This scenario assumes a large land slip or erosion which exceeds the spare pipe stock.

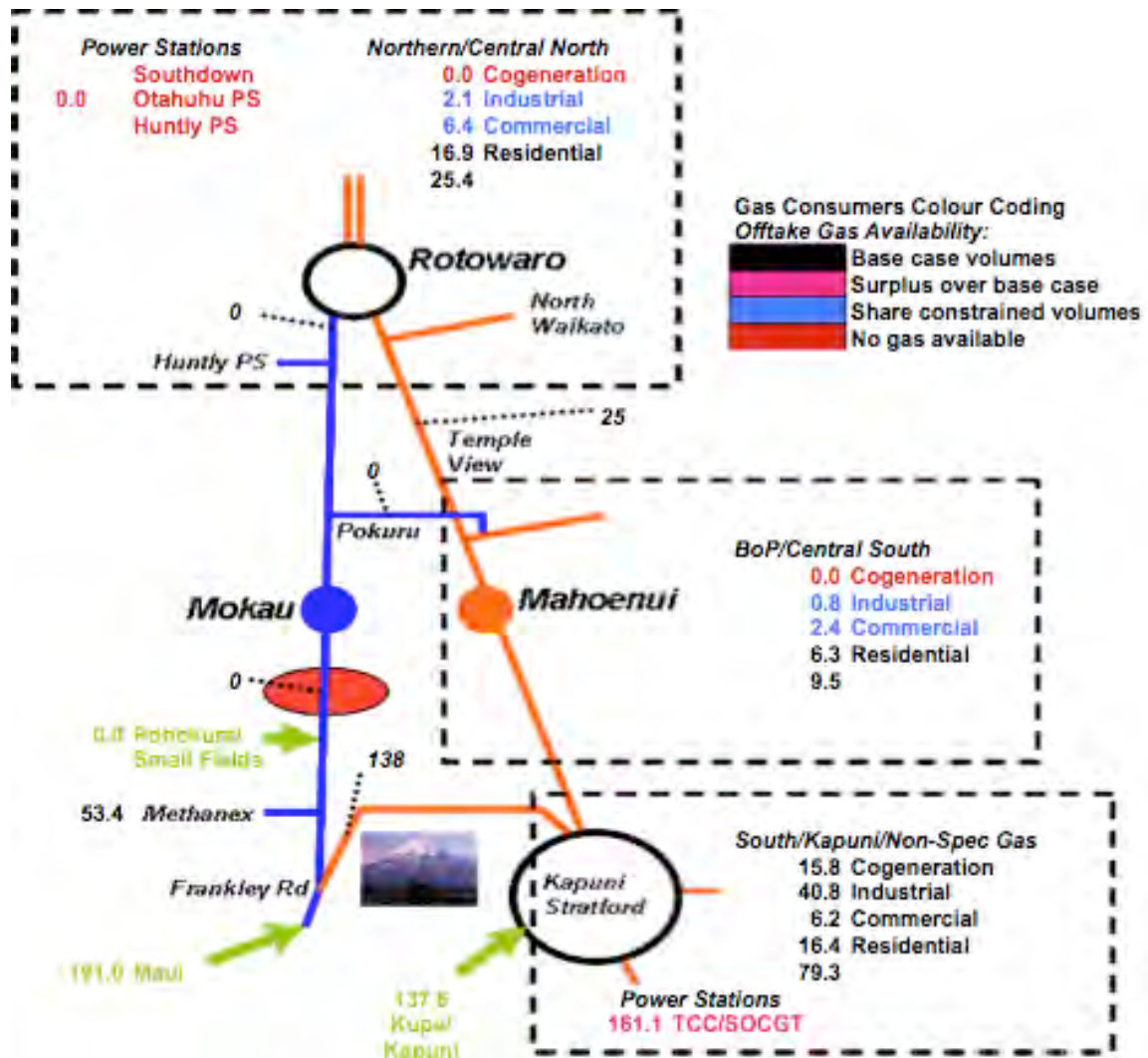


Figure 16: Maui Pipeline Failure: Gas Availability (TJ/day)

10.4 Impact on Electricity Generation

10.4.1 Generation Mix

The Huntly coal-fired power station takes up the most of the reduced gas-fired load throughout the gas shortage whilst hydro takes up a lesser share. As in the Taranaki Disaster scenario, about one third of the reduction in gas-fired generation is offset by the reduction in electricity demand from industrial plants forced to curtail their activities due to the gas shortage.

The utilization of the Huntly coal-fired power station increases to nearly 90% throughout the gas shortfall with coal consumption averaging an equivalent of nearly 3 million tonnes per annum. During the one-month gas shortage, about 120,000 tonnes of additional coal will be burnt. Output from the two southern stations increases as TCC reaches maximum output but this represents only about a 20% increase as TCC is quite highly utilized during this period in the base case.

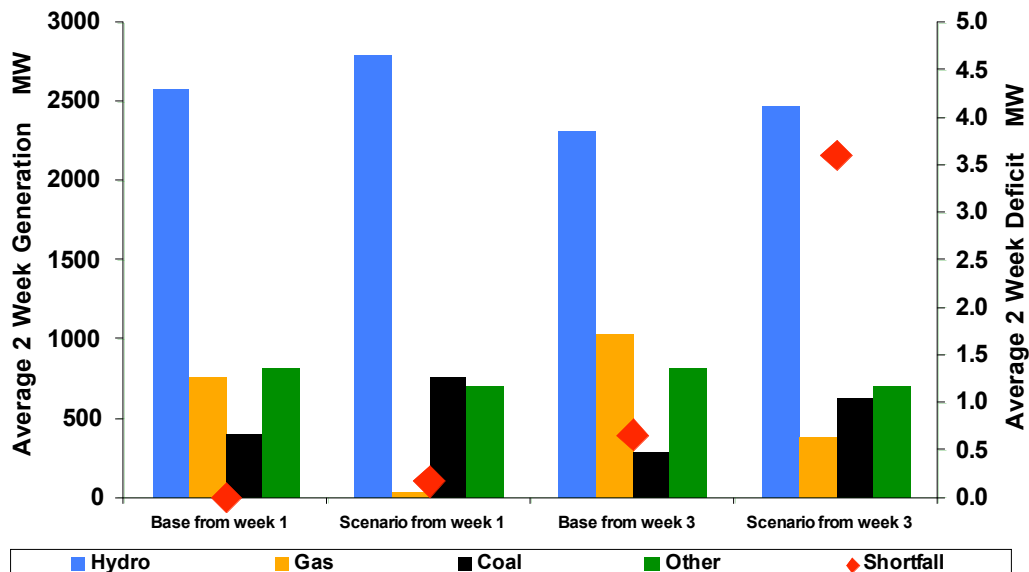


Figure 17: Maui Pipeline Failure: Electricity Generation Mix

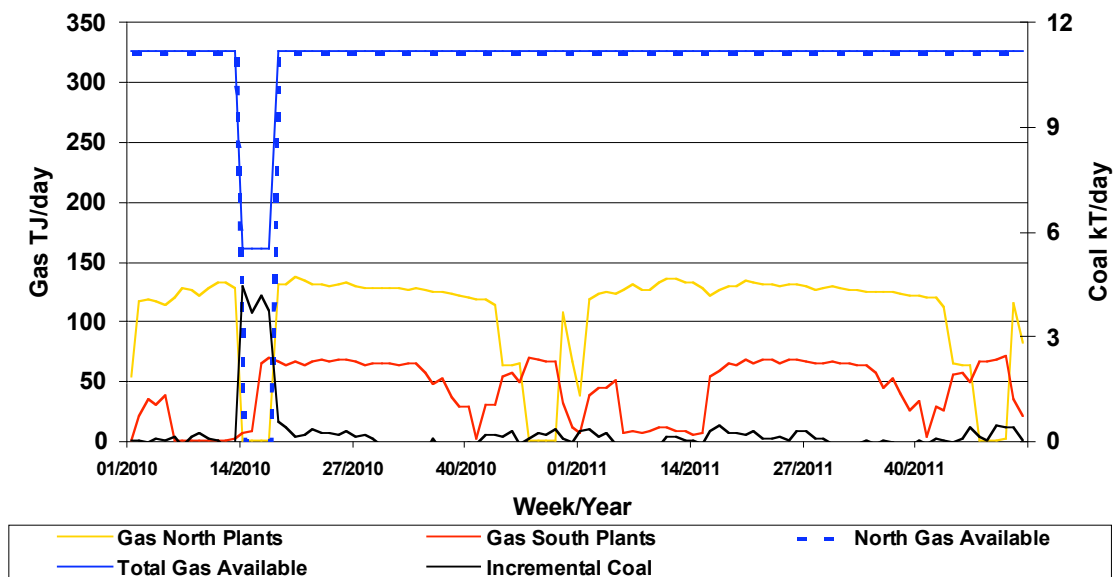


Figure 18: Maui Pipeline Failure: Gas and Coal Usage

Gas North Plants: Huntly, Otahuhu, Southdown

Gas South Plants: TCC, Stratford OCGT

Note: Gas supplies from the Pohokura and smaller onshore gas fields are excluded from Figures 16 and 18 as these are surplus to requirements during the month shortfall.

10.4.2 Generation Deficit

The potential for a deficit between generation output and demand will increase with a peak weekly average value of about 8 MW predicted by the model during the gas shortage.

10.4.3 Energy Storage

Hydro storage reserves are reduced relative to the base case as hydro takes up part of the shortfall in gas generation. This is a relatively minor impact because of the short duration of the shortfall compared to the other scenarios.

This scenario demonstrates again the importance of adequate reserves of energy storage to offset the impact of a gas shortage on electricity generation. In particular, the availability of spare capacity and coal stockpile at the Huntly power station will play a major role in providing back-up generation. Utilisation of the Ahuroa gas storage facility is not predicted in this scenario as there is surplus gas available for the southern group of power stations.

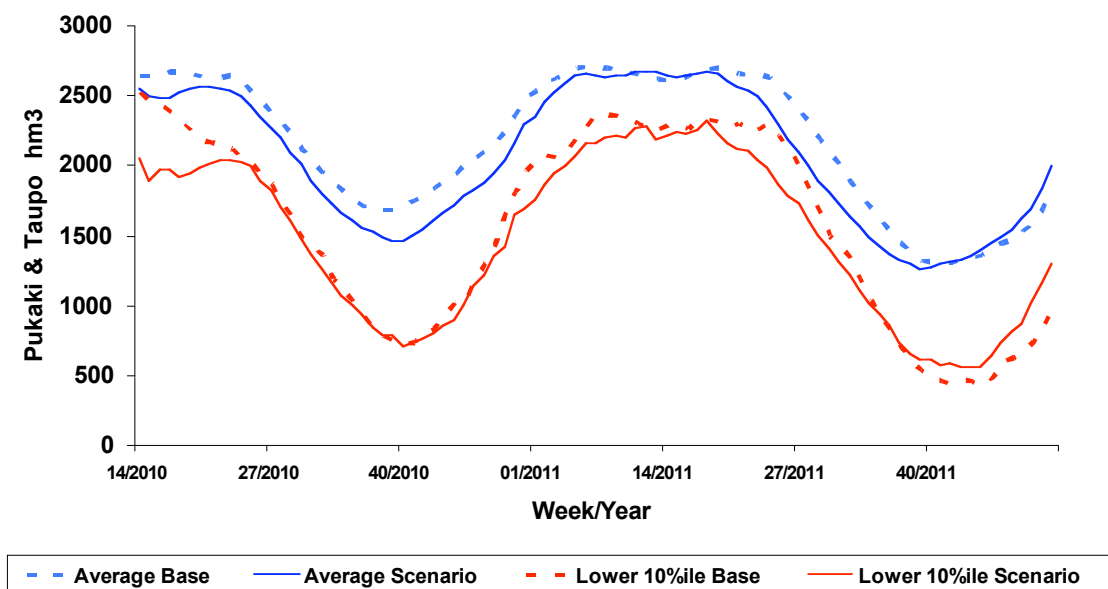


Figure 19: Maui Pipeline Failure: Effect on Hydro Storage

11. Disruption to Maui Gas Supplies

Scenario Event: Fire at Oaonui Production Station

11.1 Background

All gas entering the MDL pipeline system from the Maui gas field is processed at the Oaonui Production station. A fire at the station has the potential to cut off supplies from the field altogether. The duration of the supply failure will depend on the scope of the fire and the particular plant involved but could be extensive if large plant such as compressors required replacement from overseas.

11.2 Damage to gas system

- Flow from Maui gas field stopped for up to 1 year

11.3 Impact on Gas Operations

- No constraints within the gas transmission system
- General shortfall of gas availability to all parts of the gas transmission system
- Gas availability to the Southdown, Otahuhu, Huntly, TCC and Stratford OCGT power stations reduced to 187 TJ/day. Gas will be available for the cogeneration plants and all other industrial, commercial and residential users.
- No gas is supplied to the Methanex plants on the assumption that the power generators can pay a higher price for the available gas. Should this not be the case, there will be insufficient gas for unconstrained operation of all the power stations.

11.4 Impact on Electricity Generation

With no gas produced from the Maui field, the availability of gas to the combination of the Southdown, Otahuhu, Huntly, TCC and Stratford OCGT power stations is reduced to 187 TJ/day, compared to an unconstrained base case consumption of gas at the stations averaging 151 TJ/day throughout the twelve-month period with a maximum peak of 200 TJ/day. The generation mix is virtually unchanged.

A similar failure at Pohokura will result in a greater reduction in gas supply (224 TJ/day compared to 191 TJ/day at Maui). It is anticipated a loss of this magnitude will have some impact on the generation mix and result in greater use of the Huntly coal-fired plant during the gas shortage. This scenario has not been modeled.

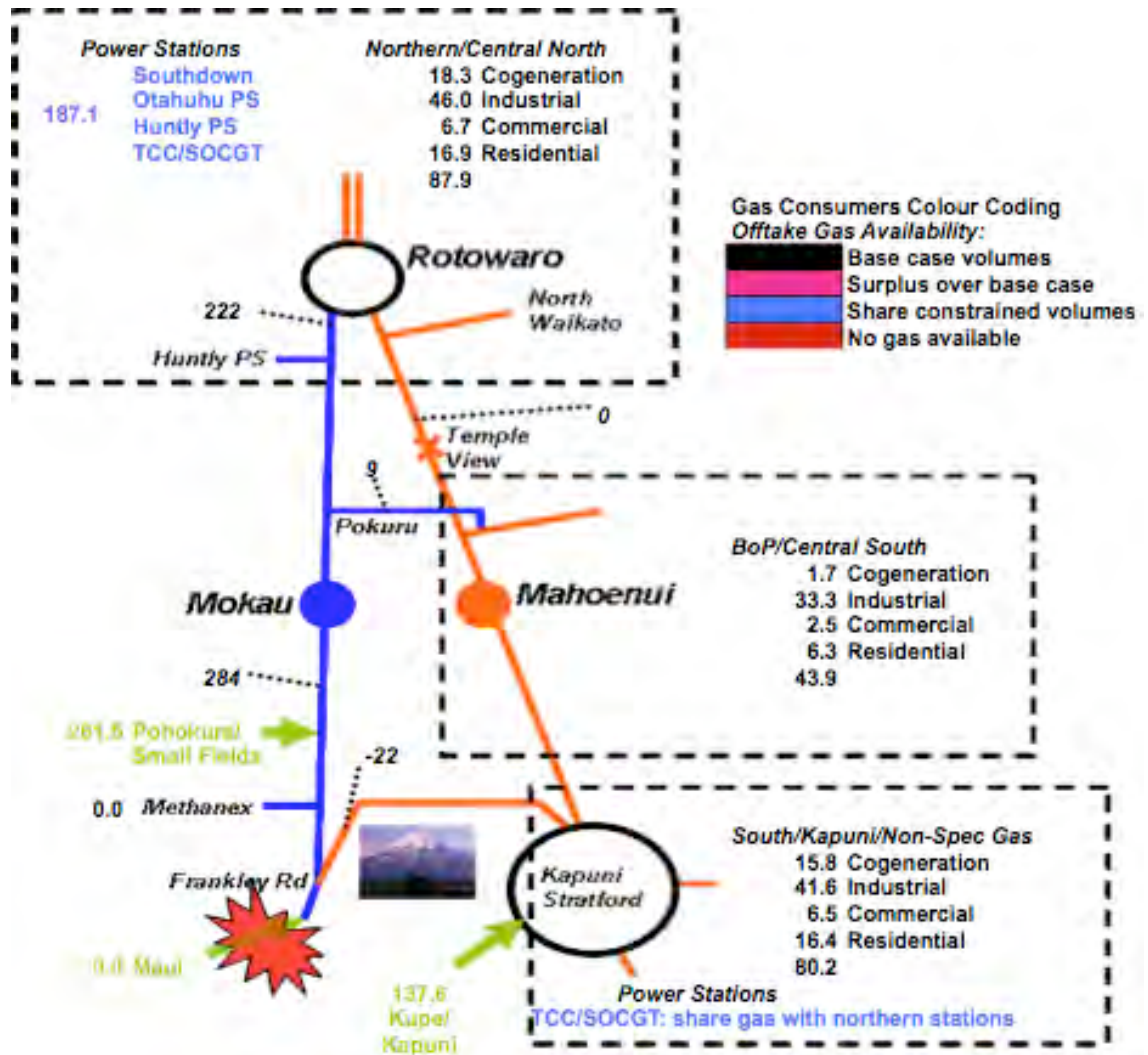


Figure 20: Oaonui Fire: Gas Availability (TJ/day)

12. Summary of Scenario Outcomes

Event	Duration	Principal Impact
Major Disaster in Taranaki Area	3 months	Reduced gas availability/MDL pipeline shut off
	3 months - 1 year	Reduced gas availability
Fire at Mokau compressor station	3 months	MDL pipeline capacity reduced
Fire at Rotowaro compressor station,	3 months	Gas availability north of Rotowaro reduced
Landslip damage to MDL pipeline	2 weeks-1 month	MDL pipeline shut off
Fire at Oaonui Production Station	up to 1 year	Reduced gas availability

Table 6: Summary of scenarios and outcomes

12.1 Gas Supply

- It is virtually impossible to conceive of a realistic scenario in which all gas supply stops. The location of the gas fields and the pipeline routes makes it most probable that some gas will be available to some segments of the market at all times. The scenarios chosen focus on gas supplies to the north of Kapuni as this is where the major power stations are located. Gas supply disruptions can occur to the south but will not have an impact on northern supplies greater than that in the scenarios chosen.
- The maximum rates of delivery from gas fields as recorded in the MDL and Vector disclosure data provides a good measure of the present availability of gas in the event of a disruption in the supply system. This availability will change over time as production from existing developments declines and depletes and new capacity comes on-stream through further development of existing fields or the discovery of new reserves. However, with no knowledge of when the gas shortfall events will occur or when new gas field developments will take place, estimates of the future location and quantity of gas availability is speculative. For this reason only gas from existing fields and confirmed developments at current deliverability rates is used in the scenarios.
- The gas storage development at Ahuroa, with a potential to deliver up to 100 TJ/day, has the potential to offset the impact of shortfalls in gas supply to the power stations in the Taranaki region.
- None of the scenarios chosen assume a concurrent failure of both the Maui pipeline and Vector's Central (South) pipeline, which run side by side for much of the route and would result in the closure of all gas supplies north of Taranaki. This has been excluded because of the improbability of such failures occurring simultaneously and the likelihood that the Vector line can be re-instated relatively quickly as the small pipeline

size can be more readily procured and transported to the failure location. The following comments regarding the industrial, commercial and residential markets are based on the assumption that the northwards Vector pipeline is available in the event of a MDL pipeline failure.

- The MDL pipeline carries the large majority of gas northwards from Taranaki. A complete failure of this pipeline will have a major impact on gas supplies to power stations and the industrial sector. Reduced capacity in the pipeline caused by failure at the Rotowaro compressor station will affect power generation but will allow sufficient gas to be supplied to industrial users.

12.2 Gas Markets

- With no constraint to the Vector Central (South) pipeline there will be sufficient gas availability and transmission pipeline capacity to supply all residential gas markets under each scenario. However, the concurrent failure of both the Vector and Maui pipelines would close off gas to this sector, resulting in significant costs to reactivate consumers when gas supplies are re-instated.
- The industrial and commercial markets are afforded a lower priority than residential for gas supplies but higher (with the exception of Methanex) than electricity generation because of the smaller gas offtake at each site. Under the scenarios examined, the critical factor determining supplies to these markets is the available capacity of the MDL pipeline. Gas must be rationed north of Taranaki to industrial and commercial users if no gas can be delivered through the Maui pipeline. However, with reduced capacity in the MDL pipeline, for example with failure of the Rotowaro or Mokau compressor stations, these markets can still be supplied in full. The availability of gas in each scenario for the various types of consumer is summarized in Table 7.

Scenario:							
	Base	Taranaki Disaster		Mokau Fire	Rotowaro Fire	Maui Pipeline Failure	Oaonui Fire
		3 months	12 months				
	TJ/day	TJ/day	TJ/day	TJ/day	TJ/day	TJ/day	TJ/day
Electricity Generation*	325	23	117	325	325	161	187
Methanex	53	0	0	53	53	53	0
Industry <i>incl cogen</i>	157	60	157	157	157	60	157
Commercial	16	15	16	16	16	15	16
Residential	40	40	40	40	40	40	40
	590	138	329	590	590	329	399
Pohokura	224	0	0	224	224	0	224
Small Onshore	38	0	0	38	38	0	38
Maui	191	0	191	191	191	191	0
Kupe	70	70	70	70	70	70	70
Kapuni	68	68	68	68	68	68	68
	590	138	329	590	590	329	399

*Includes Southdown Combined Heat and Power Station

Table 7: Gas availability for the base case and scenarios

- Because of their scale of operation, power stations will be the first gas consumers curtailed in a gas shortfall under the gas contingency regulations. The reduction in gas availability will not be evenly spread amongst the stations and will depend on the nature and location of the constraint to gas supplies. Whilst some stations have no or reduced gas availability, others may enjoy surplus gas availability in some scenarios as

illustrated in Figure 21. This particularly applies when there are gas transmission constraints north of Taranaki, resulting in surplus gas for the TCC and Stratford OCGT stations. Of the scenarios considered, failure of the MDL system presents the greatest threat to electricity generation, most notably a complete failure such as a washout of the pipeline and to a lesser extent failure of the Rotowaro compressor station.

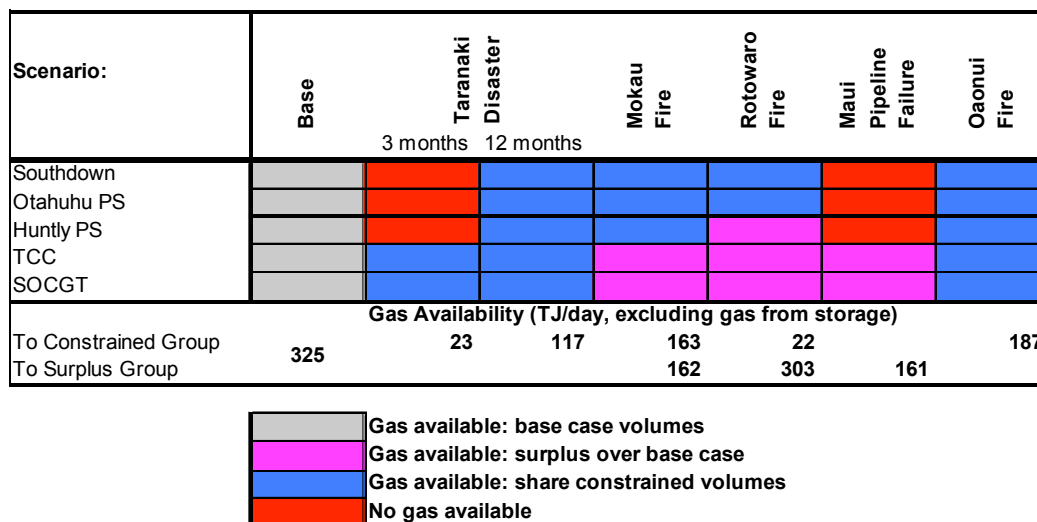


Figure 21: Gas availability to power stations for the base case and scenarios

- Concurrent changes in demand for electricity during a gas shortfall only become significant when industrial and commercial consumers face gas supply constraints (Scenarios 1 and 4). The response of the industrial sector to a gas shortfall is the principal uncertainty in determining the subsequent change in electricity demand, with little or no relevant empirical experience nor survey data available to support the assumptions made in this study. This applies less to the very large industrial consumers of gas where the significance of gas supply can be more readily identified and quantified. Residential demand for electricity is unchanged as gas supplies to this sector are maintained under each scenario. The reduction in electricity load assumed in the scenarios is summarized in Table 8.
- The response of the many smaller industries and commercial operations to a gas shortfall is uncertain, with little or no relevant empirical experience nor survey data available. Many of these operations have no contingency plan to replace gas in the event of a shortfall and operations would be curtailed, at least in the short term. Australian experience suggests that gas supply failure will have an impact on a significant portion of industrial and commercial activities. However, over an extended period some gas consumers may switch to other fuel options, including electricity, to sustain operations. To provide a conservative setting for overall electricity demand, it is assumed that electricity demand in Scenarios 1 and 4 for the light industrial sector will increase by 39 MW and that in the commercial sector by 1 MW.

Scenario:	Taranaki Disaster		Mokau Fire	Rotoraro Fire	Maui Pipeline Failure	Oaonui Fire
	3 months	12 months				
	MW	MW				
Methanex	3.5	3.5	0.0	0.0	0.0	3.5
Industry <i>net of cogen</i>	142.6	0.0	0.0	0.0	142.6	0.0
Commercial	-1.0	0.0	0.0	0.0	-1.0	0.0
Residential	0.0	0.0	0.0	0.0	0.0	0.0
	145.1	3.5	0.0	0.0	141.6	3.5

Table 8: Reduction in electricity load for scenarios relative to base case

- Contingency actions by industry are likely to have secondary impacts on other parts of the industrial sector, particularly when fuel switching options are pursued:
 - Total reduction in industrial (including the dairy industry) and commercial gas use is about 50 TJ/day in the Taranaki Disaster and Maui Pipeline Failure scenarios where no gas can be delivered through the MDL pipeline. Some portion of this could be taken up over time by diesel and LPG suppliers over the effected areas. This will place some pressure on the fuel suppliers, but LPG is more likely to be constrained with existing infrastructure for a 7 PJ pa market compared to diesel with a market of 110 PJ.
 - The availability of diesel and LPG combustion and storage equipment will impede potential fuel switching. Most of the combustion equipment will need to be imported. Some temporary storage equipment for diesel may be available or quickly constructed in New Zealand although this is less likely for the more sophisticated and expensive LPG storage. RMA consents may present bottlenecks when installing this equipment.
 - There is little potential to supplement available gas supplies by mixing in complementary products such as LPG due to gas specification constraints.
 - This study has not investigated the indirect impact of affected industries on the activities of industries not directly affected by the gas shortage.

12.3 Electricity Generation

- Not all of the scenarios result in a significant change to patterns of electricity generation. This applies when gas availability is reduced through failure at the Mokau compressor station or the Oaonui production station but not to a level below the demand for gas at the power stations. However, such an outcome may change should gas consumption and production patterns change in the future or a larger source of gas such as Pohokura be affected. In the case of fire at the Oaonui production station, the analysis has not taken account of constraints to gas-fired generation brought about by the decreased flexibility and responsiveness of gas supply precipitated by the loss of Maui gas. This is likely to be exacerbated by the gas supply and purchasing contracts in place as each participant in the industry moves to minimize its exposure to the failure.

- While electricity transmission capacity has been considered in this study, issues regarding the secure operation of the grid are beyond the scope of the study. Issues related to system voltage support, for example, have not been considered.
- The spare capacity of the Huntly coal-fired power station to stand in for gas-fired power stations affected by gas shortages is critical to meeting overall electricity demand. This is demonstrated in the Taranaki Disaster, Rotowaro Fire and Maui Pipeline Failure scenarios where there is a significant reduction in available gas-fired generating capacity. With the Huntly coal station available, the reduction in gas availability does not present a crisis in electricity generation with generation deficits remaining at manageable levels.
- The non-availability of the coal-fired Huntly power station is not directly addressed in this study but would result in a greater call on hydro generation in the event of a gas shortage with the attendant uncertainties in reservoir levels and available transmission and generation capacity. Any moves to partly or fully decommission this facility should take into account its potential contribution to security in an emergency situation.
- An adequate stockpile of coal is necessary at Huntly to meet the sudden requirement for additional generation at the plant. In the more extreme gas shortage scenarios, coal-fired power station will operate at near maximum capacity for extended periods of time. It is probably not possible to deliver coal to the station as quickly as it is consumed during this time.
- The Ahuroa storage facility is utilized only in the Taranaki Disaster scenario, when gas supplies to the TCC and Stratford OCGT power stations is constrained and there is limited or no gas for more northerly stations. This does not presuppose that the storage facility will not be used for commercial reasons not reflected in the modeling.
- Hydro reserves will be reduced when gas-fired generation output is constrained by a gas shortfall. However, as hydro is expected to play a secondary role to coal in replacing gas-fired generation, the reduction in reserves is relatively minor and of a manageable dimension.
- Reliance on Huntly coal is higher if the gas shortfall occurs during a dry year and minimum hydro reserves can be maintained at about the same level as the base case in all scenarios.
- When gas supplies are curtailed to industrial gas consumers, a significant portion of the reduced generation from gas-fired power stations may be offset by the consequent reduction in electricity consumption at these industrial plants. This warrants a more thorough investigation of the relationship between gas supply and electricity demand in the industrial sector.
- Increases in costs of generation have not been specifically investigated in the analysis but in all scenarios where the generation mix is affected by the gas shortage the short run marginal cost of generation will increase as more expensive forms of generation are used in place of gas.
- The results tend to present a worst case insofar as the gas shortages are assumed to occur at the time of year when demand for gas for generation is increasing with the approach of winter. Also, the availability of gas has been determined after the maximum demand for gas in other markets has been deducted from the total gas available.
- Output from this analysis is based on industry-wide least-cost scheduling of generation capacity. When gas supply is interrupted, the least-cost model revises generation planning, fully taking into account the reduced supply. In practice, information sharing between market participants will not be complete and individual companies will follow their particular commercial prerogatives unless the electricity industry is coordinated in a manner similar to that intended in the gas contingency regulations.

Appendix: Assumptions for Gas Outage Study

Gas Fired Generation

Plants listed in the table are modelled as dispatchable, within the limits of their fuel supply.

Plant	Installed Capacity (MW)	Heat Rate (GJ/MWh)	Maximum Gas Consumption (TJ/day)
Otahuhu B	385	7.05	65.1
Huntly U5 (e3p)	400	7.08	68.0
Huntly U6	45	9.50	10.3
Southdown	190	10.00	45.6
Taranaki CC	398	7.30	69.6
Stratford CT	200	8.90	42.7

Model Time Horizon

Three year period from 1 January 2010 to 31 December 2012. Gas outage begins on 1 April 2010. Time horizon allows for lake refill effects to be accounted for. Perhaps one or more studies also for the period 1 January 2012 through to 31 December 2014, to investigate effect of the upgraded HVDC.

Demand Data

Using 2008 as the base, 1.9% load growth in each island. 2008 load will have been reduced by the high prices that occurred for part of the year, but 2009 – 2010 demand likely to be reduced by lower the level of economic activity.

Gas Supplies

Under normal conditions, assume TCC, Otahuhu B, Southdown, Huntly units 5 and 6 are all unconstrained by fuel supplies and can simultaneously run at full capacity.

Cogeneration

Grid connected cogeneration plants are modeled as operating at zero cost, but output is limited to the average output observed over a number of years in the past. Southdown is modelled as a dispatchable plant, but with a limited availability, determined as the average of a number of year's of actual generation. Also, Southdown is assigned a higher priority when gas supplies are limited.

The following are modelled as cogeneration plants:

- Glenbrook
- Kapuni
- Kawerau
- Kinleith

Huntly Operation

Units 1 to 4 run exclusively on coal.

Assume stockpile size is 707,000 tonnes, as applied at 31 December 2008.

1.7 million tonnes of coal delivered by Solid Energy at a uniform rate throughout the year

Assume 700,000 tonnes per year of Indonesian coal.

HVDC

620 MW until 1 April 2012, then 1200 MW. Consider the option for Pole 1 to operate at 200 MW and Pole 2 at 700 MW for one period of four weeks.

Southward transfer is limited to 300 MW until 2012, and then increases to ??

New Plant

Fully commissioned on 1 Jan 2010

- Ngawha 2 15 MW
- Kawerau 90 MW
- West Wind 143 MW
- Te Rere Hau 38.5 MW

1 April 2010

- Stratford OCGT 200 MW (gas, 8.9 GJ/MWh)
- Nga Awa Purua 132 MW (Rotokawa 2)

1 April 2011

- Te Mihi 30 MW

EC assume full Te Mihi replacing Wairakei from 2011, giving an extra 57 MW. Contact specify two stages of construction, 2x75 MW in 2011 and 1x75 MW in 2016. Assume 30 MW increase from 2011.

1 April 2012

- Hawea Dam turbine 17 MW

1 April 2013

- Wairau Hydro 73 MW
- Tauhara Geothermal 240 MW
- Waitohora Wind 177 MW

EC MDS5 assumes 150 MW diesel peakers in 2013 and 2014. Assume that these are unrealistic, but that Whirinaki has unlimited fuel.

1 April 2014

- Rodney 120 MW

Additional plant possibilities:

- 3 units, 100 MW each at Huntly, assume LMS 100 units, as at Stratford.

Transmission System Constraints

Assume normal constraints apply, but system constraints will not be modelled in detail.

Identify to the extent possible, likely transmission constraints into the Auckland area. These can be due to voltage issues, if no Otahuhu or Huntly generation.

Gas Storage

Contact's Ahuroa gas storage facility is considered in some scenarios. The capacity of this is assumed to have 10 PJ in storage on 1 April when the failure occurs. Maximum daily offtake rate of 100 TJ/day. When operating at full capacity, the TCC and Stratford open cycle plants require 112.7 TJ per day.

Initial Lake Levels

On 1 January 2010, assume that the following initial lake levels apply.

Initial Reservoir Levels	
Reservoir	Reservoir Fraction Full
Taupo	0.75
Waikaremoana	0.75
Cobb	0.75
Coleridge	0.75
Tekapo	0.9
Pukaki	0.9
Ohau	0.5
Hawea	0.75